Powder Core Development and High Frequency Considerations

Brad Van Fleet
Sales Engineer
Overview

• Powder Core Development
  • Expansion of Kool $\mu$® Max product line
  • XFlux®, new permeabilities
• Shapes Development
  • Round Leg U-Core Geometries
  • EQ26
• R&D Pipeline
  • Improved High Flux (58 and 59 materials)
  • High Frequency Powder Core Material

• High Frequency Considerations
  • Current Material Comparison
    • Perm vs. Frequency
    • Core Loss
Kool $\mu$ MAX

- Superior DC Bias performance and lower losses compared to standard Kool $\mu$
- Lower cost compared with MPP and High Flux.

<table>
<thead>
<tr>
<th>General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeability</td>
</tr>
<tr>
<td>Alloy Composition</td>
</tr>
<tr>
<td>Saturation Flux Density</td>
</tr>
<tr>
<td>Curie Temperature</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
</tr>
<tr>
<td>OD Size Range (mm)</td>
</tr>
<tr>
<td>Coating Color</td>
</tr>
</tbody>
</table>

- 19$\mu$, 75$\mu$, 90$\mu$ and Shapes (E-Cores, U-Cores, Blocks) in Development
<table>
<thead>
<tr>
<th>Material (60µ)</th>
<th>DC Bias at x Ls (Oe)</th>
<th>Core Loss (mW/cm³)</th>
<th>Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80%</td>
<td>50%</td>
<td>(W_{1000 \text{ G}, 50 \text{ kHz}})</td>
</tr>
<tr>
<td>Kool Mµ MAX</td>
<td>68</td>
<td>135</td>
<td>190</td>
</tr>
<tr>
<td>Kool Mµ</td>
<td>43</td>
<td>95</td>
<td>210</td>
</tr>
<tr>
<td>XFLUX</td>
<td>89</td>
<td>175</td>
<td>680</td>
</tr>
<tr>
<td>High Flux</td>
<td>87</td>
<td>165</td>
<td>350</td>
</tr>
<tr>
<td>MPP</td>
<td>60</td>
<td>106</td>
<td>175</td>
</tr>
</tbody>
</table>
Kool Mµ Max vs. Kool Mµ
XFLUX—new permeabilities

• Silicon Iron Alloy Powder
• Cost 40-50% less than High Flux
• Applications:
  • Low & medium frequency chokes, where inductance at peak current is critical.
  • Where High Flux would be used but cost is a constraint.

• Available in Toroids, E-Cores, U-Cores, and Blocks
XFLUX – 75µ and 90µ

Now available in 050 (13.5mm OD) to 102 (103mm OD) size toroids.

• 19µ coming in next few months
Shapes Development

- Round-Leg U-Cores
  - Rounded blocks and cylinders
  - Helical Windings
  - 84mm x 30mm Block + 30mm Cylinder
  - Expanding to industry standard sizes

- EQ Shapes in Powder Core
  - Focused on EQ 26/19, three leg lengths.
  - Available in 60µ XFLUX
  - High Flux and Kool Mµ development next
  - EQ 32 will be next available size
Magnetics’ R&D

• Improved High Flux and Next Generation High Flux (59)

<table>
<thead>
<tr>
<th>Material (60µ)</th>
<th>DC Bias at x Ls (Oe)</th>
<th>Core Loss (mW/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Flux</td>
<td>87</td>
<td>165</td>
</tr>
<tr>
<td>Improved High Flux</td>
<td>100</td>
<td>185</td>
</tr>
<tr>
<td>Next Gen High Flux (59)</td>
<td>125</td>
<td>215</td>
</tr>
</tbody>
</table>

• High Frequency Powder
  • Optimize Losses from 500kHz to 3MHz
  • Material selection still under consideration – looking at Sendust base
    • Potentially multiple materials optimized for different frequency ranges
  • Looking to market to determine best options
    • Where is highest demand?
**Kool Mµ MAX**

**New Perms**  
19µ, 75µ & 90µ

**New Shapes**  
Blocks, E, U, I

**XFLUX**  
75µ and 90µ, Addition of 19µ

**New Geometries**  
EQ26 in XFLUX  
EQ32  
Round Block/Cylinder Expansion  
Other EQ sizes/materials

**58 Series**  
Improving standard High Flux

**59 Series**  
Next Generation High Flux

**High Frequency Material**  
Optimized for High Frequency Losses
HIGH FREQUENCY CONSIDERATIONS

• Focused testing on lower loss materials
  • MPP, Kool Mµ, Kool Mµ MAX

<table>
<thead>
<tr>
<th>Material (60µ)</th>
<th>DC Bias at x Ls (Oe)</th>
<th>Core Loss (mW/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80%</td>
<td>50%</td>
</tr>
<tr>
<td>MPP</td>
<td>60</td>
<td>106</td>
</tr>
<tr>
<td>Kool Mµ</td>
<td>43</td>
<td>95</td>
</tr>
<tr>
<td>Kool Mµ MAX</td>
<td>68</td>
<td>135</td>
</tr>
</tbody>
</table>

• Comparing permeability versus frequency up to 10 MHz for 60µ

• Comparing core loss at 500kHz, 1MHz, 2MHz, and 5MHz (60µ)
High Frequency Considerations – $\mu$ vs. Freq 60$\mu$
High Frequency Considerations – Core Loss Data Compilation
High Frequency Considerations – Core Loss Data Compilation

26u High Frequency Loss Comparison

- Core Loss (mW/cm³)
- Flux Density (Gauss)

Lines for:
- 2 MHz
- 1 MHz
- 500 kHz

Legend:
- MPP
- Kool Mu
- Kool Mu MAX
High Frequency Considerations – Summary

• Summary Table

<table>
<thead>
<tr>
<th>60µ</th>
<th>MPP</th>
<th>Kool Mµ</th>
<th>Kool Mµ MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Loss 1MHz, 100G</td>
<td>150 mW/cc</td>
<td>175 mW/cc</td>
<td>165 mW/cc</td>
</tr>
<tr>
<td>Core Loss 1MHz, 250G</td>
<td>1110 mW/cc</td>
<td>1100 mW/cc</td>
<td>1090 mW/cc</td>
</tr>
<tr>
<td>Core Loss 5MHz, 35G</td>
<td>215 mW/cc</td>
<td>260 mW/cc</td>
<td>250 mW/cc</td>
</tr>
<tr>
<td>Core Loss 5MHz, 70G</td>
<td>1000 mW/cc</td>
<td>1100 mW/cc</td>
<td>1040 mW/cc</td>
</tr>
<tr>
<td>µ vs. f 5MHz</td>
<td>-5.4%</td>
<td>-7.6%</td>
<td>-6.5%</td>
</tr>
<tr>
<td>µ vs. f 10 MHz</td>
<td>-17.4%</td>
<td>-22.0%</td>
<td>-19.6%</td>
</tr>
</tbody>
</table>

• Future Steps
  • Further High Frequency Testing and Curve Development
  • High Frequency Bulletin
  • High Frequency Powder Material
Presentation Conclusions

• Kool $\mu$ MAX available in 26$\mu$ - 60$\mu$
  • 19$\mu$, 75$\mu$, 90$\mu$ and shapes soon
• Higher perm XFLUX (75$\mu$ & 90$\mu$)
• New Shapes Development
  • EQ26 and Round Leg U-Cores
• R&D Development
  • High Flux Improvement and High Frequency Powder Material
• High Frequency Testing
  • $\mu$ vs. Frequency Performance: MPP > Kool $\mu$ MAX > Kool $\mu$
  • Core Loss Performance
QUESTIONS?