Flux Based Control and Monitoring of Active Magnetic Bearings Using Ultra-Thin and Flexible Bismuth Hall Sensors

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Motivation: Ultra-thin and flexible Hall sensors for electrical machines and drives

Magnetic flux based control approach[1]

| Task: | Measurement of the flux density of up to 2.3 T in narrow air gaps between stator and rotor (< 0.5 mm) is crucial |

| Requirement: | Magnetic field sensors have to be mounted on the curved surface of the stator pole in the air gap |

| Issue: | Conventional rigid Hall sensors are too thick |

| Aim: | Ultra-thin and flexible Hall sensors have to be developed |

Envisioned applications of ultra-thin flexible Hall sensors providing flux feedback

- Improvement of the dynamic performance of high precision machining tools
- Enhancement of stiffness, damping and rotor positioning accuracy of AMBs
- Manufacturing the combustion engine pistons and high quality optical components
- Pumping systems: cost reduction and miniaturization
- Angular encoding systems for rotor position detection
- Monitoring magnetic field and rotor unbalance

Ultra-thin flexible Bismuth Hall sensors

Fabrication of the Hall sensors[2,3]

- Commercially available flexible PCB providing 4 contacts for Hall element
- Deposition of Chromium (layer 4 nm thick)

Characterization of the flexible Bismuth Hall sensor elements

Thickness dependence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Bismuth film thickness</td>
<td>2 µm</td>
</tr>
<tr>
<td>Total height</td>
<td>150 µm</td>
</tr>
<tr>
<td>Supply current</td>
<td>10 mA</td>
</tr>
<tr>
<td>Hall responsivity</td>
<td>-1.4 V(A·T⁻¹)</td>
</tr>
<tr>
<td>Temperature stabilized</td>
<td>25 °C</td>
</tr>
<tr>
<td>Signal to noise ratio</td>
<td>32 dB</td>
</tr>
<tr>
<td>Temperature range (sensed)</td>
<td>0 to 180 °C</td>
</tr>
<tr>
<td>Temperature coefficient</td>
<td>-0.25 mV/(A·T·K)</td>
</tr>
<tr>
<td>Max bending radius</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Flux based control of single-axis AMB[2]

- Single-sided two-axes AMB setup with asynchronous motor: Air gap of 680 µm
- Homopolar bias magnetization 0.9 T and heteropolar control magnetization
- Two stators each with four stator poles
- Nominal force of the radial bearing: 460 N

Monitoring a two-axes radial AMB[3]

- Bismuth Hall effect sensors on commercial flexible printed circuit board (PCB)
- Total thickness is 150 µm including cabling
- Achieved magnetic field resolution after amplification: 25 mT (sat supply current 10 mA)
- Real-time flux density monitoring realized

Conclusions

- Ultra-thin (150 µm) and flexible Bismuth Hall sensors are fabricated and characterized
- Integration of flexible sensors onto the curved stator pole is successfully realized
- Flux based control and monitoring of a single- and two-axes AMB is demonstrated
- Angular encoding of the rotor position of an eBike was shown using the flexible sensors

References