

Fluxgate for Motor Diagnostics

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Permanent magnetic synchronous motors are commonly used in industrial applications. These motors are attractive because of their high efficiency, increased torque-current ratio and high power density yet compact and lightweight. These performance and size attributes make them ideal in industrial automation, Hybrid Electric Vehicles (HEV) traction motors and robotics. However, faults are unavoidable in these designs as a result of manufacturing defects, material lifetime, and intermittent use. Motor monitoring and fault detection are important in providing lifetime and performance, while minimizing safety concerns and potential costly shutdowns.

Fault monitoring techniques can include electrical (electrical signature analysis, motor current analysis, motor circuit analysis), mechanical (vibration, torque) thermal (infrared, ultrasonic) and magnetic (magnetic field, flux density) analysis. The most prevalent fault-detection methods for permanent magnetic synchronous motors are vibration signal analysis and phase current information. However, there are issues associated with each of these techniques. Vibration fault monitoring is typically effective under stationary conditions. When used in nonstationary applications, there is a need for extensive signal processing. For phase current analysis, fault signatures are dependent on a variety of design specific configurations including stator winding, winding type, load levels and fault location. Thus, operating point dependency is needed for setting detection thresholds. As a result of these issues with both vibration and phase current, fault detection techniques in the final solutions can be costly, bulky, and impractical in some applications.

Magnetic Fault Detection

An alternative is using the leakage flux spectra to detect magnetic field related faults. Magnetic field faults include defects, such as magnets that are broken, flawed or deformed and demagnetization due to external magnetic fields and temperature. One of the advantages of using the leakage flux density is it allows for detection of magnetic defects in both the time and frequency domain. [Figure 1](#) shows the radial axis leakage flux component comparison of a healthy motor versus 20% broken magnet motor versus a 50% broken magnet motor in the time domain.

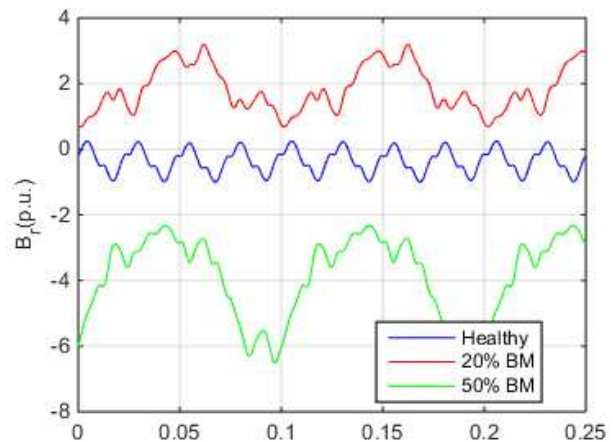


Figure 1. Time Domain Signature

[Figure 2](#) shows the same radial axis leakage flux component comparison in the frequency domain.

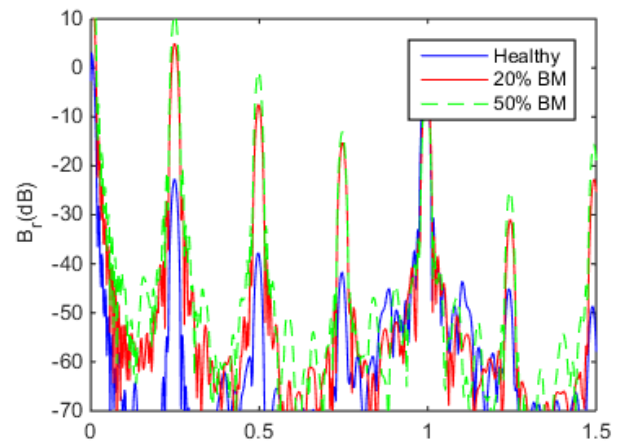


Figure 2. Frequency Domain Signature

Both figures above show distinct measurable differences between healthy motors and damaged motors. Another advantage of using the leakage flux density is that the fault signatures are independent of speed. Where other detection techniques, such as current-based analysis, require different threshold settings for motor speed, the flux density has similar signatures at different motor speeds, as shown in [Figure 3](#) and [Figure 4](#).

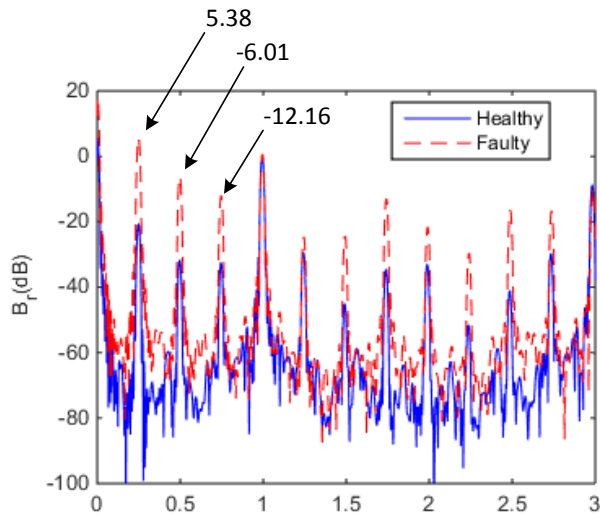


Figure 3. Frequency Signature of 600 RPM

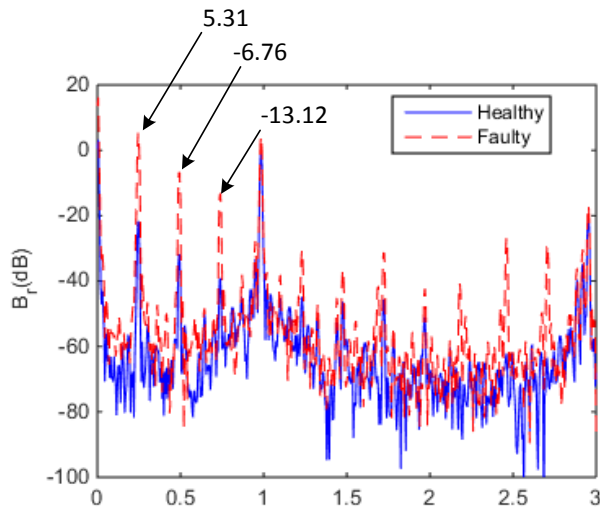


Figure 4. Frequency Signature 3000 RPM

DRV425 Integrated Fluxgate Sensor

The [DRV425](#) is a precision integrated fluxgate magnetic field sensor capable of measuring magnetic field strength from the nT to mT with a bandwidth of 47 kHz. The low offset, offset drift, and noise of the fluxgate sensor, combined with the precise gain, low

gain drift, and very low nonlinearity provided by the internal compensation coil, results in unrivaled magnetic field measurement precision. The [DRV425](#) comes in a 4-mm x 4-mm QFN package allowing for easier installation on or around the motor frame. The internal fluxgate sensor in the [DRV425](#) is a single-axis sensor. The [DRV425](#) will measure magnetic fields only in its axis of sensitivity allowing for the installation of the sensor to detect radial, tangential or z-axis component of the magnetic field. By using three [DRV425](#) devices, all three axis components of the magnetic field can be detected in a small form factor.

There are advantages to using fluxgate sensors to detect magnet defect faults in permanent magnetic synchronous motors, such as easy mount on the motor frame, both frequency- and time-domain analysis remote sensing, and speed-independent fault detection. The high sensitivity, low noise, low temperature drift, and small size enable the [DRV425](#) device to be an excellent choice for use in motor-monitoring and fault-detection applications.

Acknowledgment

The author would like to acknowledge Dr. Bilal Akin at The University of Texas at Dallas, Electrical Engineering Department for his research using the [DRV425](#) device. All diagrams are created from the research of Dr. Akin.

Table 1. Alternative Device Recommendations

| Device | Optimized Parameters | Performance Trade-Off |
|----------------------------|--|--|
| DRV5055-Q1 | Automotive, Ratiometric, Linear, Hall Effect Sensor, SOT-23 or TO-92 package | Magnetic field measurement range μT to mT |

1 Related Documentation

T. Goktas, M. Zafarani, K. W. Lee, B. Akin and T. Sculley, "Comprehensive Analysis of Magnet Defect Fault Monitoring Through Leakage Flux," in IEEE Transactions on Magnetics, vol. 53, no. 4, pp. 1-10, April 2017. doi: 10.1109/TMAG.2016.2617318

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