Sensor magnet quality control using a magnetic field camera

Dr. Koen Vervaeke, Magcam NV, Romeinse straat 18, B-3001 Leuven, Belgium

Abstract

A method is presented for magnetically characterizing 2-pole rotary encoder magnets, which are widely used in angular encoders in e.g. electric motors and rotary positioning systems. The method uses a proprietary 'Distance Filter' algorithm, which allows to extrapolate a magnetic field distribution recorded at one certain (close) distance above a magnet or magnet assembly to another (larger) distance in a very fast way and with a strong suppression of measurement noise. This allows very fast and at the same time highly accurate measurements, making the method suitable for production quality control. The 'Distance Filter' extrapolation algorithm is used in combination with Magcam's magnetic field camera systems. When the extrapolation is in the direction away from the magnet, there is a strong suppression of noise, resulting in µTesla magnetic field resolutions. This makes the Distance Filter algorithm very powerful for determining magnetic field distributions far away from a magnet, since a direct measurement at the farther distance would suffer from a poorer signal-to-noise ratio. In typical end applications, a Bx,By sensor is positioned in the center of the rotary encoder magnet at a certain distance from the magnet surface, which is typically several mm. At such distance the Bxy magnetic field is typically of the order of 50mT. The Bx,By sensor then measures Bx and By and from those calculates the in-plane angle of the magnetic field using atan2(By,Bx). Inhomogeneities of the magnetic field distribution can cause errors on this measured angle value. During quality control on such magnets, this angle error needs to be determined with high accuracy, typically in the order of 0.1° or better. By using a magnetic field camera in combination with the Distance Filter this can be achieved in a superior way.

1 Introduction

A method is presented for magnetically characterizing 2-pole rotary encoder magnets, which are widely used in angular encoders in e.g. electric motors and rotary positioning systems. The method uses a proprietary 'Distance Filter' algorithm, which allows to extrapolate a magnetic field distribution recorded at one certain (close) distance above a magnet or magnet assembly to another (larger) distance in a very fast way and with a strong suppression of measurement noise. This allows very fast and at the same time highly accurate measurements, making the method suitable for production quality control.

2 Distance Filter method

The 'Distance Filter' extrapolation algorithm is used in combination with Magcam's magnetic field camera systems [1-10]. When the extrapolation is in the direction away from the magnet, there is a strong suppression of noise, resulting in µTesla magnetic field resolutions. This makes the Distance Filter algorithm very powerful for determining magnetic field distributions far away from a magnet, since a direct measurement at the farther distance would suffer from a poorer signal-to-noise ratio.

For accurate results with the Distance Filter, the recorded magnetic field distribution must contain the full magnetic field of the measured magnet or magnet assembly, meaning that at all edges of the measured magnetic field image the magnetic field should be monotonically decreasing towards zero when going outwards towards the image edges. In practice, this means that a sufficiently large area should be measured, including extra space around the magnet.

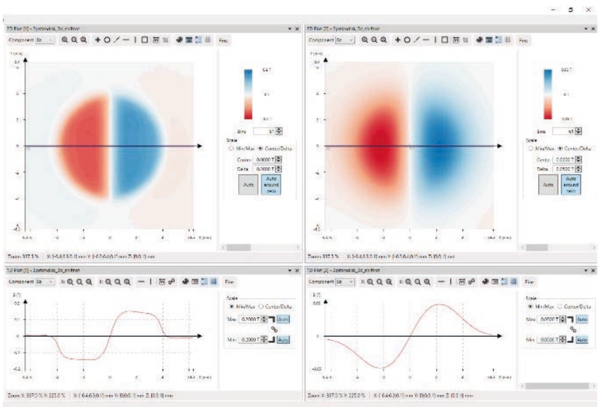

Figure 1 Measured Bz magnetic field distribution and cross section along the X direction at Z0 = 0.3mm (left) and Distance Filter result at Z1 = 2mm (right).

3 Results

Consider a cylindrical axially magnetized 2-pole rotary encoder magnet, with the cylindrical symmetry axis pointing in the Z direction. The same principle applies for diametrically magnetized cylinder magnets. The original measurement is in the XY plane at a certain height Z0 above the magnet surface. The magnetic field distribution at a different height Z1 is obtained by the Distance Filter

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method by supplying one single input parameter Delta, namely the distance between the original measurement plane and the desired plane: Delta = Z1 - Z0. When Delta = 0 the original data is retained.

Figure 1 shows the measured Bz magnetic field distribution and cross section along the X direction at Z0 = 0.3mm (left) and Distance Filter result at Z1 = 2mm (right). Hereby the value for Delta is: Delta = 2mm-0.3mm = 1.7mm.

3.1 Rotary encoder magnetic field analysis

In typical end applications, a Bx,By sensor is positioned in the center of the rotary encoder magnet at a certain distance from the magnet surface, which is typically several mm. At such distance the Bxy magnetic field is typically of the order of 50mT. The Bx,By sensor then measures Bx and By and from those calculates the in-plane angle of the magnetic field using atan2(By,Bx). Inhomogeneities of the magnetic field distribution can cause errors on this measured angle value. During quality control on such magnets, this angle error needs to be determined with high accuracy, typically in the order of 0.1° or better. By using a magnetic field camera in combination with the Distance Filter this can be achieved in a superior way as is shown below.

A magnetic field distributionmeasurement directly at the working distance of the Bx,By sensor in the above application would result in a poorer signal-to-noise ratio than a measurement very close to the magnet (typically 0.3-0.5mm). The Distance Filter makes it possible to 'preserve' the signal-to-noise ratio at close distance to remote distances, resulting in virtually noise-free magnetic field distributions.

Figure 2 2-pole axially magnetized cylinder magnet measured with MiniCube3Dmagnetic field camera

The 3D magnetic field distribution is measured at a close distance above the magnet surface using a Magcam MiniCube3D magnetic field camera [1-10] (see Figure 2).
As mentioned higher, the relevant magnetic field components for this application are the in-plane (Bxy) magnetic field and the in-plane direction (azimuthal angle) of the field in a region in the center of the magnet. These components can be analyzed as explained below.

3.2 Bxy field

The Bxy component of the magnetic field distribution is readily obtained from the Bx and By components (see Figure 3). A circle is interpolated centered on the magnet center and with a certain radius, taken to be 0.25mm in this example, typically determined by the tolerance region where the Bx,By sensor will be located in the end application. In the obtained line plot, the maximum and minimum values can be automatically detected, which can be directly used in a pass/fail test to check if they are within the tolerance window.

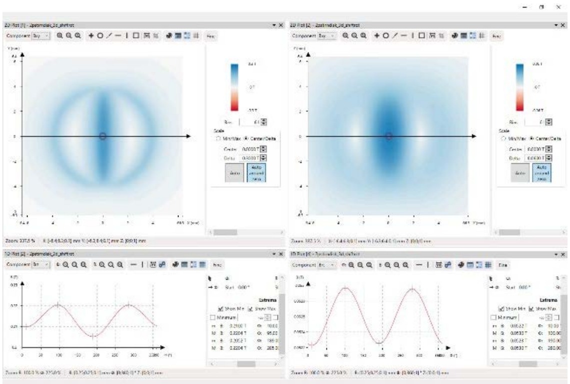

Figure 3 Bxy (in-plane) magnetic field distribution with a circle section in the middle of the magnet for Z = 0.3mm(left) and Z = 2mm (right). In the 1D Plots the minimum and maximum values are automatically detected.

3.3 Azimuthal angle

The second important quantity of the magnetic field distribution is the in-plane direction (azimuthal angle) distribution of the magnetic field. This quantity is also readily calculated from the Bx and By components of the magnetic field by using atan2(By,Bx). By analyzing the extreme values of the azimuthal angle on the same circle section as before, the angle error is directly obtained, as shown in Figure 4. By combining the results of Bxy and the azimuthal angle, a full quality control of rotary encoder magnets can be performed within seconds.

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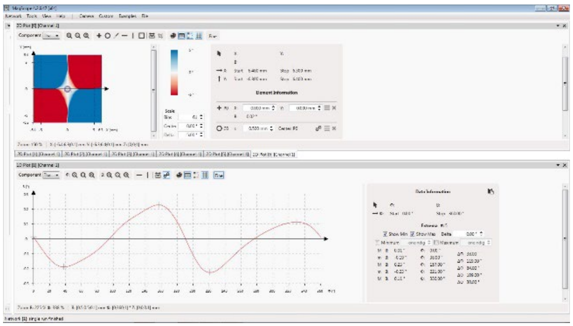

Figure 4 Azimuthal (in-plane) angle distribution with a circle section in the middle of the magnet for Z = 2mm. In the 1D Plot, the minimum and maximum values are automatically detected and give a direct measure of the angle error of the Bxy magnetic field distribution on the circle.

4 Conclusion

A method was presented for magnetically characterizing 2-pole rotary encoder magnets, which are widely used in angular encoders in e.g. electric motors and rotary positioning systems. The method uses a proprietary 'Distance Filter' algorithm, which allows to extrapolate a magnetic field distribution recorded at one certain (close) distance above a magnet or magnet assembly to another (larger) distance in a very fast way and with a strong suppression of measurement noise. This allows very fast and at the same time highly accurate measurements, making the method suitable for production quality control.

Using this method, the Bxy field and azimuthal angle atan2(By,Bx) are analyzed in a center region of the magnet. In end applications, inhomogeneities of the magnetic field distribution can cause errors on the measured angle value. During quality control on such magnets, this angle error needs to be determined with high accuracy, typically in the order of 0.1° or better. It was shown that this can be achieved by using a magnetic field camera in combination with the Distance Filter algorithm in a fast and accurate way.

5 Literature

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