magnetfabrik bonn

Magnet Technology Compact

Current Applications and Technologies with Permanent Magnets

Magnets for high-precision linear position detection for automotive and industrial applications

Permanent magnets are used as a cost-effective solution for high-precision linear position detection in dirty environments. For absolute position detection, two field components must be scanned. This can only be achieved with very exact magnetisation. Magnetfabrik Bonn specialises in cost-effective polymer-bonded hard ferrite magnets that optimally fulfil the requirements of sensors thanks to their complex magnetisation. With a pole pitch $\ll$ 1 mm, we also offer solutions for applications in the µm range.

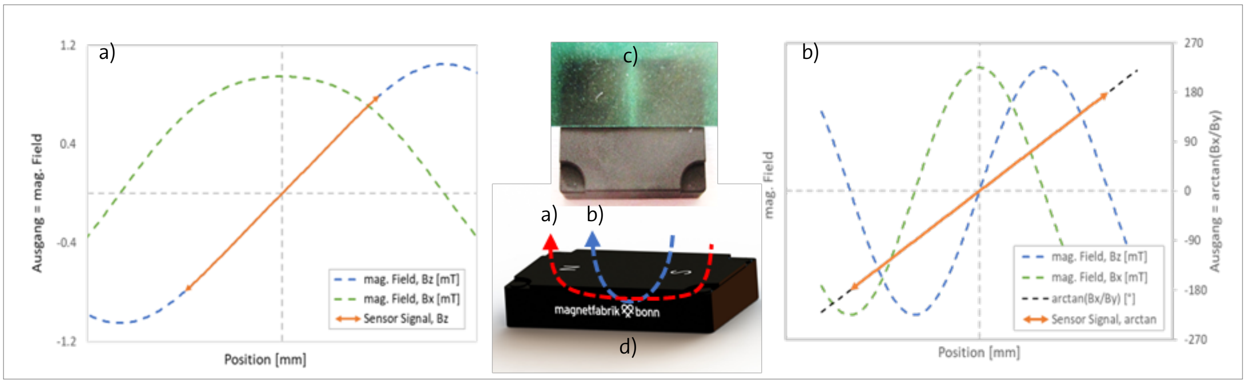

Figure 1: Measuring principles for linear position detection – a) 1D sensor of the axial field component – b) 2D sensor with angle calculation from two field components – c) Visualisation of the magnetic poles – d) Schematic diagram of the magnet

A linear position detection system measures the position of an object, such as a shaft, a piston or a switch, which can only be moved in one direction. For applications with small linear displacements of up to several tens of millimetres, there are very precise and cost-effective magnetic sensor solutions for harsh environments. The advantages include high resolutions, low power requirements, non-contact measurement, miniaturisation potential and robustness against temperature and dirt. As the magnetic field penetrates non-magnetic materials and is hardly affected by dirt and water, such systems are ideal for many automotive and industrial applications. The magnets with complex magnetisation and geo-

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metries are manufactured cost-effectively from plastic-bonded materials using injection moulding. With proper handling, the magnets can be used for several decades.

Details:

Position detection systems have a magnet that moves relative to a magnetic field sensor. The sensor detects a change in the strength or angle of the magnetic field and converts this into information about the linear position.

Conventional applications employ multi-pole magnetic strips. Detecting pole transitions with a digital magnetic field sensor allows the displacement to be recorded incrementally. The resolution of this method is limited by the number of poles and the pole width accuracy. – Current applications with analogue sensors and the availability of 2D and 3D Hall sensors enable virtually unlimited resolution.

There are two different methods of analogue absolute linear position detection.

With 1D measurement, only a single component of the field is scanned (Fig. 1a). The temperature and an axial position tolerance influence the measurement. A position detection system with 1D sensors must be able to handle non-linear sensor outputs, smaller measuring ranges and measurement errors due to sensor position tolerances. In most cases, non-linearity is corrected using a software solution, e.g. look-up tables.

In modern methods, detection is performed by a 2D sensor that simultaneously detects two components of the magnetic field at a single location (Fig. 1b). The two signals can be combined to enable field angle detection to improve resilience to positional shifts and temperature fluctuations. A linear sensor output signal can be realised over a wider magnet position range.

In cost-driven areas such as the automotive industry, 1D magnetic position detection has prevailed over 2D detection despite all these shortcomings. This is because the industrial production of 2D or angle sensors is much more complex and costly than the production of simple one-dimensional Hall sensors. Nowadays, applications for 2D sensor technology have increased significantly due to magneto-resistive angle sensors and the development of vertical reverberation.

Numerous implementations are possible on the magnetic encoder side. The most cost-effective and simplest variant is the use of cylindrical or cuboid magnets magnetised along the effective length (Fig. 2a). Displacement generates a continuous change in the radial and axial field strength. The magnet must be significantly longer than the measuring path and therefore requires considerable installation space, increasing the material costs accordingly.

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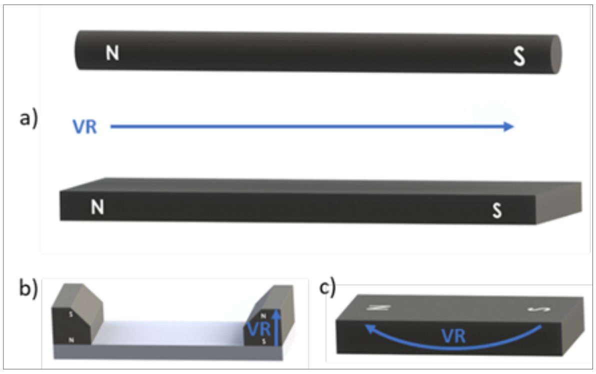

Figure 2: a) Round or block magnets with axial preferential direction (VR) – b) Block magnets mounted on pole piece – c) Block magnet with customised magnetisation (anisotropically sprayed in the magnetic field)

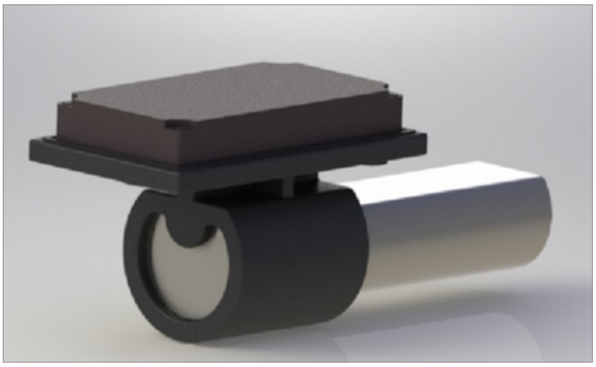

Figure 3: Linear magnet with holder, mounted on an axle

A better solution results from a combination with soft magnetic components (Fig. 2b). Here, the field linearity can be optimised for a smaller magnet system size. However, the encoder magnet is more complex and requires an additional component as well as additional joining technology, i.e. bonding or overmoulding, meaning extra costs.

More flexible solutions that account for the magnet size and field linearity are based on a customised magnetisation of the encoder (Fig. 2c). Magnetfabrik Bonn has developed solutions for this in which the required complex magnetisation is embossed directly in the injection mould in order to meet the sensor requirements in the best and most cost-effective way possible using polymer-bonded hard ferrite magnets.

Differential measuring sensors offer stray field-robust solutions for electrical machines. Sensors used in e-mobility, in particular, e.g. in braking systems, are located close to high-current cables; the differential sensor principle has become established here.

Nowadays, magnetic encoders are supplied together with mounting components. Fig. 3. shows the magnet moulded onto a holder. Magnetfabrik Bonn will work with you to develop your polymer-bonded magnet to be moulded onto bushings/holders or directly onto the shaft/axle.

Automotive applications

Linear magnets play an important role in a variety of automotive applications. One frequent use is to measure the position of the pedals and then supply data to the control unit. Other applications include use in automatic transmission systems, e.g. for detecting gear changes or clutch pedal position and for brake detection (see Fig. 4).

In wheel suspension, linear sensors detect the path of the shock absorbers, and linear measuring principles also help in power steering, ESP and short rotation (throttle valves).

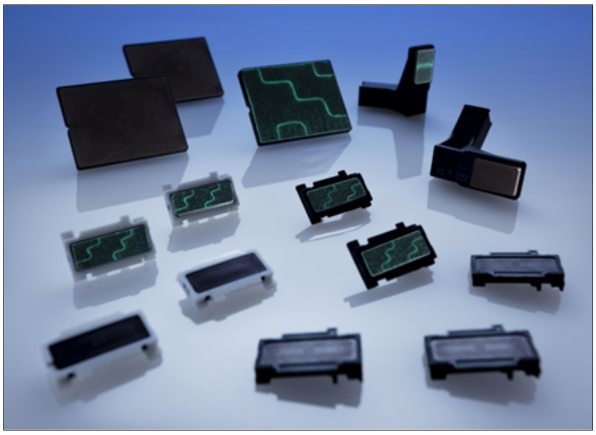

Figure 4: Examples of linear magnet systems in transmission control (magnetisation partially visualised with pole foil)

Industrial and consumer applications

In industry, linear magnetic sensor systems detect the position of conveyor belts, cylinders, gears and other moving objects in assembly lines and automated systems. In consumer applications, these sensors are used in devices such as printers, photocopiers, 3D scanners, joysticks and other high-precision applications.

Solution for longer distances

Magnetfabrik Bonn has developed and patented a spiral magnetisation for longer distance measurement. This magnetisation can be implemented on bar magnets with practically unlimited length.

In applications, two 1D sensors can detect the radial field components (Fig. 5), or a lateral angle sensor detects an angle signal proportional to the path. As the two sensors are coupled and moved parallel to the centre axis of the rod-shaped encoder magnet and the magnet axis is at a right angle to the radii of the sensors, this arrangement offers excellent linearity and robustness against mounting tolerances and temperature.

If the field strength increases over the position due to a change in the magnet cross-section or a decrease in the distance from the encoder magnet to the sensors caused by slightly tilting the axis of movement to the magnet axis, the measuring method can simultaneously determine a rough digital equivalent of the number of passes made from 0° to 360° from the ratio of both field components, the fine detection of the position $\arctan\left(\frac{B_1}{B_2}\right)$ and the absolute field strength $\sqrt{B_1^2 + B_2^2}$.

We have successfully implemented this magnetisation in bar magnets made of polymer-bonded isotropic material; differential sensor principles have also been successfully applied.

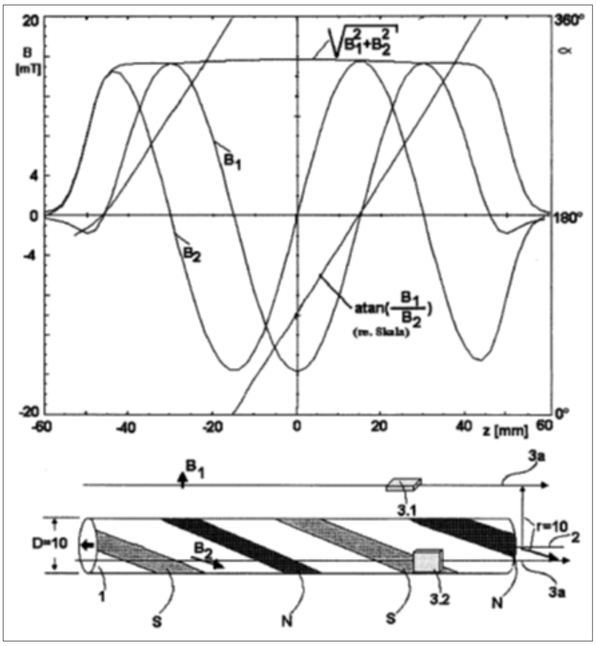

Figure 5: Differential measuring principle for spirally magnetised rods (image from MFB patent DE19836599)

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Magnetisation for µm resolution

For small linear displacements, magnets with a very small pole pitch are used to achieve high resolution (Fig. 6).

Magnetfabrik Bonn has developed a bipolar magnetisation technology that uses a magnetic pulse process rather than writing as a cost-effective solution to meet sensor requirements with polymer-bonded hard ferrite magnets. The technology enables pole pitches from roughly 500 µm. Due to the bipolar magnetisation, the amplitude of the flux density is significantly higher compared to structured magnets. Based on this method, the offset of the signal can be suppressed in the case of flat geometry.

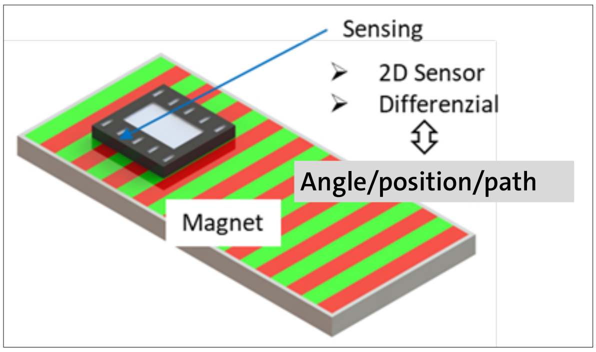

Figure 6: Bipolar magnetisation with small pole pitch

Fig. 7 shows an example of magnetisation patterns with a pole pitch of 500 µm. The measurement/control of the magnetised tracks shows an accuracy of less than 20 µm for the pole pitch.

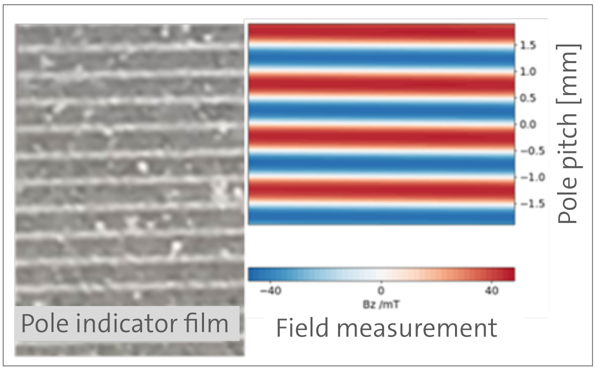

Figure 7: Magnetisation pattern with a pole pitch of 500 µm for very fine linear position detection

The newly developed multi-track magnetisation process can be used both in absolute angle detection for robot joints and in torque sensor technology. Moreover, the use of a multi-track magnetic ring enables high-resolution angle detection of up to 20 bits. For example, torque can be detected by attaching multi-track magnetic rings and magnetic angle sensors to two ends of a torsion bar.

The cost-effective magnet material and the carrier-free design are major advantages over the magnet systems available on the market. The selected magnet material, a hard ferrite in a PA matrix, is suitable for applications with temperatures up to 160 °C (depending on the thermal and mechanical load). The material can be adapted and the magnetisation principle transferred to different magnet geometries depending on the application. The principle can be applied directly to linear measurements of a multi-track encoder.

We'd be happy to work with you to develop your perfect magnet solution. Reaching our goals together! Put us to the test!

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