Production-related measuring and testing technology for permanent magnets (in sensors and motors)

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1. Introduction

A permanent magnet, often also called a permanent magnet, is a magnet that can maintain its magnetic effect permanently without energy supply. Permanent magnets have one or more north and south poles on their surface. Permanent magnets have an extremely wide range of applications. They have become indispensable in the automotive industry, aerospace, acoustics, telecommunications, power generation and many other areas. Physically, a permanent magnet is a metastable system. Variations in chemical composition and processing can lead to variations in magnetic properties. In order to achieve the optimum performance for the respective application, careful inspection of the unprocessed parts and the finished magnets is indispensable.

This article presents the most common measuring methods for the magnetic properties of permanent magnets and explains their advantages and limitations. The focus is on production-related processes and equipment that can be used for incoming or outgoing goods inspection or for in-line inspections.

2. Permanent magnets everywhere

Due to their strong magnetic forces, permanent magnets are used in many different areas. The possible applications are as diverse as the magnets themselves [1]. From industry and households to technology and construction - examples of applications for permanent magnets can be found everywhere. Permanent magnets are often needed in electronics and industry. Here they can be used in motors, generators or sensors, for example. Permanent magnets are also found in household appliances such as hoovers or refrigerators. Permanent magnets are available in different designs and sizes. Among other things, they can be manufactured as ring magnets, disc magnets, cuboid magnets or bar magnets.

Today, permanent magnets are made from special alloys of metals such as iron (Fe), nickel (Ni) and aluminium (Al) with additions of cobalt (Co), manganese (Mn) and copper (Cu). Despite the large number of materials, only three groups of materials have prevailed for reasons of application and price: ceramic magnets such as hard ferrites, metallic magnets such as AlNiCo and plastic- or rubber-bonded magnets. The sintering process produces particularly strong permanent magnets, such as neodymium-iron-boron (NdFeB) and samarium-cobalt (SmCo). These materials (neodymium and samarium) belong to the so-called rare earth metals. The element neodymium has the strongest magnetic force of all known materials and is therefore one of the most frequently used permanent magnets. However, the sintering process limits the shape flexibility of the magnet and injection-moulded, plastic-bonded magnets offer a high degree of freedom in magnet geometry, albeit with somewhat weakened magnetic properties.

Figure 1: ELSOMA C10 flux density meter during incoming goods inspection of magnetic pole rings

3. Increasing demands on measuring and testing technology

The quality requirements for permanent magnets are increasing across the fields of application. In the field of sensor technology, the demands on the accuracy of magnetic measuring systems, consisting of magnetic sensors and permanent magnets as measuring standard, are constantly increasing. Rotary encoders or motor feedback systems have to achieve ever higher precision, either to realise more precise positioning or to enable better efficiency and lower torque ripples.

There is a similar development in magnets for electric motors. The uniformity and direction of magnetisation in segment magnets has a great influence on the noise and vibration behaviour (NVH), and especially in the automotive sector there are currently strongly increasing requirements.

These requirements place new demands not only on the sensors used, but also on the magnets used and consequently on the measurement technology used for incoming and outgoing goods inspections along the value chain.

Several factors need to be considered when choosing the measurement method. For development and testing under laboratory conditions, devices with improved accuracy increase the order of magnitude of accuracy. For series characterisation, non-destructive measurement methods are more economical and therefore more likely to be used. For mass production quality control, economic factors (i.e. cost as a function of throughput and measurement time per magnet) and required accuracy are of particular importance. Based on the relative importance of these factors during the life cycle of the product, very different methods and equipment are used [2, 3, 4].

In early development phases, where the primary focus is on materials research tasks, vibrating sample magnetometers (VSM) are often used. This is a magnetometer for determining magnetic properties (e.g. the magnetic moment) of a sample. The sample to be examined is set into periodic oscillations and the voltage thus induced is measured.

For the measurement of magnetic field strength and magnetic induction, a flux density meter or field strength meter with Hall probe has been the most commonly used device for a long time. The use of Helmholtz coils (Fig. 2) to measure the remanence in open circuits and the magnetic moment makes this device ubiquitous in the laboratory and in the incoming inspection of magnets [5, 6].

If the homogeneity and the 3D components of the magnetic field need to be detected, 3D magnetic mappers are used (Figure 3) [7]. Such devices, however, are rather designed for laboratory use and should be used under tightly controlled environmental conditions. For measurements close to production, it is more a matter of robustness, flexibility and economy, which leads to the use of other types of measuring devices.

Figure 2: Fluxmeter with Helmholtz coil

Figure 3: a) 3D magnetic mapper

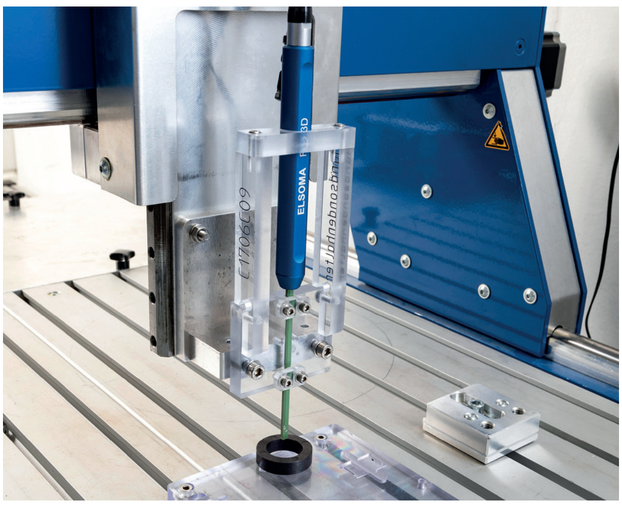

Figure 3: b) Close-up

4. Flux density meters for production-related tests

The measurement of magnetic quantities can almost always be traced back to the measurement of a magnetic flux. Therefore, a fluxmeter is the most versatile measuring instrument in magnetic technology [4]. In order to meet the special requirements of magnetic measurements close to production, ELSOMA GmbH, based in Schwerte near Dortmund, has specialised in the development of flux density meters for stationary and angle-based measurements.

An example is the ELSOMA C10 (Fig. 1), a modular device that can perform a variety of measurement tasks in the production environment. In the case of disc-shaped or rectangular dipole magnets, as they are very often used for on- and off-axis angle measurement or for switching operations, material inhomogeneities or manufacturing defects can lead to asymmetrical magnetisation or to inhomogeneous magnetic field characteristics. With the C10 flux density meter, such errors are detected much faster than with previous solutions, such as Helmholtz coils.

This portable solution can be used flexibly for incoming and outgoing goods inspections as well as in the service area. The device can be easily integrated into assembly or measuring cells using Ethernet and USB interfaces as well as an optional digital I/O interface. The configuration is very user-friendly and the evaluation of the measurement results is done via web interface.

The axially or radially magnetised component to be tested is typically placed in a specific fixture (Fig. 4). A special, highly sensitive and precise 3D sensor chip detects all three magnetic field components with just one measurement. The measuring device provides the user with both the flux density components and the solid angles of the flux density vector. This allows magnetic misalignment angles on magnets to be detected quickly and precisely.

Simple and flexible integration into automated production lines is made possible by the C10 portable flux density meter, which is equipped with a rechargeable battery and features Ethernet and USB interfaces as well as a digital I/O interface. A browser user interface supports quick configuration of the device and visualisation of measurement results. Customer-specific software extensions are possible at any time. An internal data memory simplifies the monitoring of measurement series for quality assurance or incoming goods inspections. These measurement series can be easily retrieved via the network interface. In addition to the above-mentioned devices with 3D probe, ELSOMA offers a wide range of other axial and transverse measuring probes to expand the measuring device. With the help of these probes, flux densities in the range of 10 µT to 5 T can be measured with a resolution of up to 1 µT and a measuring error of less than 1 percent.

Figure 4: ELSOMA C10 flux density meter with measuring device

The demand for magnetic angle encoder systems or magnetic rotary encoders is continuously increasing. Consequently, the need for fast, precise measurement technology to check and ensure the quality of the two-pole and multi-pole ring and cylinder magnets used is also increasing. The flux density of the magnetic field must be measured precisely, productively and cost-effectively on several coded tracks. This is where the CE-marked ELSOMETER® A05 flux density meter comes in for angle-based measurements. The device has a special, highly sensitive and precise 3D sensor chip for detecting all three magnetic field components with just one measurement.

The magnet to be tested is mounted on a drive shaft with a backlash-free preloaded bearing by means of an interchangeable mounting. This shaft is driven by a toothed belt in order to avoid any possible interference field influence from the motor. The angle of rotation of the shaft is measured using a high-resolution optical angle measuring system as a reference measuring system. The factory-calibrated 3D Hall sensor measures the flux density with a resolution of 10 µT and a measurement uncertainty of less than ± 1.25 %. Individual software solutions for evaluating the measurement results can be implemented and customer-specific adaptations and extensions are possible at any time. The device can be used flexibly for incoming or outgoing goods inspections, as several interfaces simplify integration into automated production systems. It creates measurement reports in accordance with the new DIN SPEC 91411 „Requirements for the technical representation of magnetic dimensional standards in construction drawings“ [8]. In addition to flux density deviations, measured variables such as poll length or pollage deviations can be measured and displayed.

The C10 and A05 flux density meters are ideally suited for measuring tasks at companies in the following application areas:

- Magnet manufacturer
- Magnet users
- Encoder manufacturer
- Sensor manufacturer
- Motor manufacturer
- Automotive supplier

5. Outlook

Favoured by the significantly increased demand for magnets for electric motors as well as for sensors, there is currently a lot of innovation in the field of magnetic technology. New magnetic alloys with lower proportions (or no) rare earth materials are being developed [1] and new production processes, e.g. sputtering of hard magnetic layers [7, 9, 10], are also reaching series maturity. Last but not least, new applications are leading to completely new demands on magnets and the associated measurement technology. It is not getting boring for the manufacturers of magnetic measuring instruments. ELSOMA is currently developing a new generation of even more precise flux density measuring instruments, based on the requirements of the new DIN SPEC 91479 „Characterisation of measuring standards for magnetic displacement and angle measuring systems“. At the same time, the economic efficiency must be maintained in order to be able to use such devices in a production environment.

6. References

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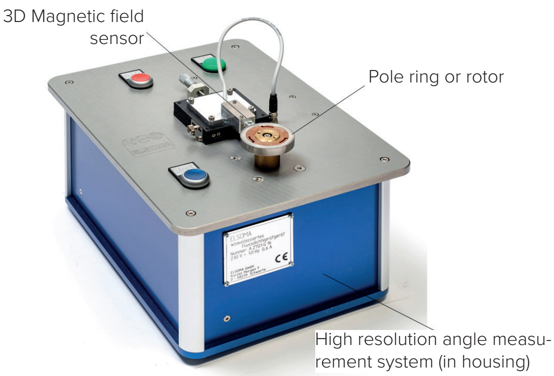

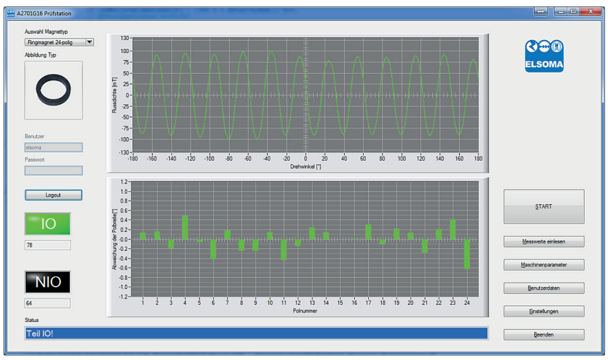

Figure 5: a) ELSOMA A05 angle-based flux density meter b) Evaluation according to DIN SPEC 91411