High-precision press solutions for permanent magnets in EVs and green energy generation

As the demand for electric vehicles and renewable energy technologies continues to grow, so too does the need for high-performance permanent magnets. These critical components, particularly NdFeB magnets, require advanced production methods to achieve the required magnetic properties and geometric precision. This article explores the role of pressing technologies in magnet manufacturing, with a focus on DORST Technologies' solutions designed to ensure consistent quality, material efficiency, and process control in modern magnet production.

Our understanding of magnetic properties has evolved significantly since the discovery of magnetite, with early advancements in Europe tracing back to ancient Greece. The first permanent magnets produced with Powder Metallurgy (PM) emerged in the form of aluminium-nickel-cobalt (AlNiCo) magnets in the 1920s and 1930s. In the 1950s, their range expanded with hard ferrites, and was further broadened in the 1960s and 1970s with the discovery of rare earth magnets made from samarium-cobalt (SmCo) and, later, neodymium-iron-boron (NdFeB) alloys.

To this day, NdFeB magnets are recognised as the strongest type of permanent magnet, driven by their high energy product. A magnet's energy product (written as BH_{max}) is a measure of the strength of a permanent magnet, calculated by the point on the magnet's demagnetisation curve where the product of B (magnetic flux density) and H (magnetic field strength) is largest, relative to its size.

Any increase in magnetic properties can only be achieved through advances in production technology, making the pressing process a crucial step in magnet production. DORST Technologies supplies equipment for various stages of magnet manufacturing: equipment for spray drying material, pressing technology with forces from 15-1,600 tonnes – some designed for inert atmospheres to accommodate materials sensitive to atmospheric oxygen – and custom magnetising coils and rectifiers to facilitate compaction in a magnetic field. Automation solutions are available to ensure effective cleaning and handling of the pressed magnets.

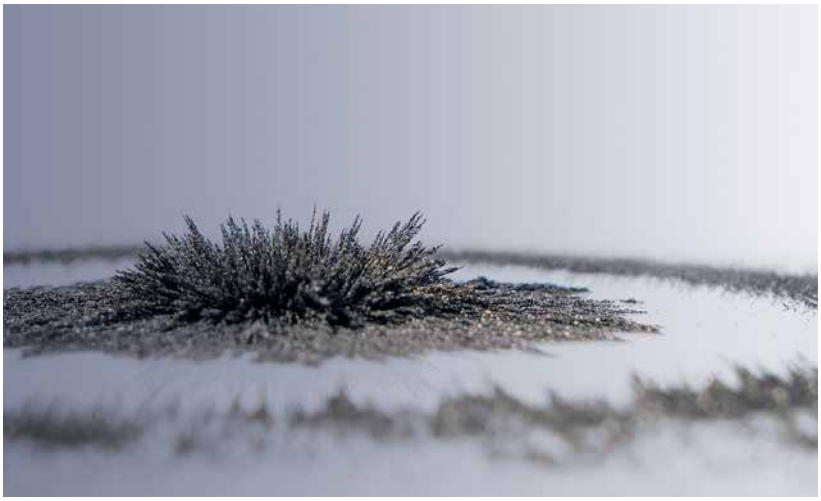

Fig. 1 According to the European Raw Materials Alliance (ERMA), demand for rare earth magnets is set to dramatically increase in the coming decade (Courtesy DORST Technologies)

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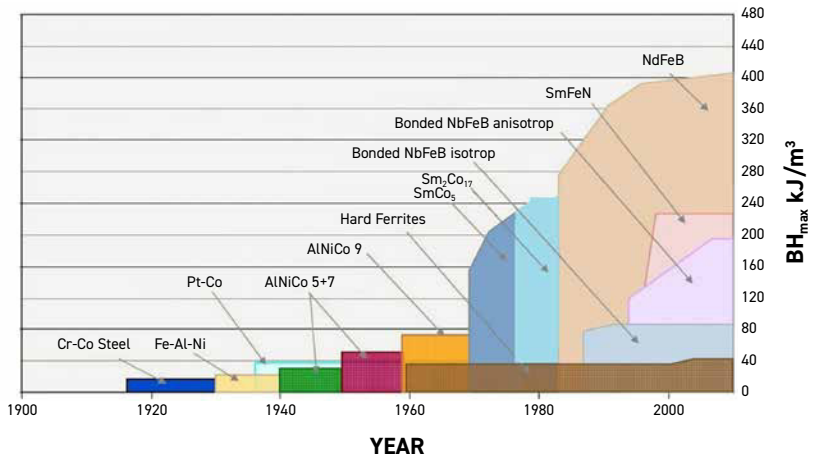

Fig. 2 Evolution of BH_{max} (Energy Product) in permanent magnets from 1900 onwards, measured in kJ/m³ (Courtesy DORST Technologies)

Fig. 3 Key markets for magnet technology: energy, mobility, medical, and aviation (Courtesy DORST Technologies)

"...discoveries of rare earths outside China, coupled with support programmes in the US and the European Union, such as the European Critical Raw Materials Act, are expected to lessen the dependencies on China formed over the past twenty years."

Renewable and green technologies drive market development

Growing awareness of global warming has resulted in the demand for technologies and solutions that reduce CO_2 emissions. Magnet technologies are required in the expanding renewable energy market, particularly for wind power and energy storage, as well as for the electric motors used in electric vehicles (EVs).

According to the European Raw Materials Alliance (ERMA), demand for rare earth magnets in modern gearless wind turbines is expected to reach 15,000 tonnes by 2027, while annual demand for electric vehicle (EV) motors could rise to 70,000 tonnes by 2030. Meeting this growing demand is challenging, given China's dominance in rare earth production, however there are efforts in Europe and the US to develop independent supply chains.

China has previously imposed export restrictions on rare earths and is likely to continue this practice in the future. However, discoveries of rare earths outside China, coupled with support programmes in the US and the European Union, such as the European Critical Raw Materials Act, are expected to lessen the dependencies on China formed over the past twenty years.

Individual press solutions from 15 to 1,600 tonnes

DORST Technologies began building axial magnet presses in the 1980s, initially using mechanical presses as the basis for its designs. The company has since developed wet presses featuring a magnetic alignment system for producing hard ferrite magnets. Its current presses which exert forces between 15-200 tonnes are exclusively powered by servo-electric drives. For pressing forces ranging from 300-1,600 tonnes, however, servo-hydraulic drives have proven to be the most

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effective solution. Over the past two years, the company has received numerous orders for axial magnet presses with these pressing forces, all of which have been built, delivered, and commissioned.

One of the key benefits that sets servo-electric and servo-hydraulic presses apart from mechanical presses is their ability to offer completely independent CNC-controlled closed-loop operation for each axis. Each axis operates independently, providing the flexibility and precision required for highly accurate pressing cycles. If necessary for axial compaction, this enables additional closed-loop-controlled relative movements of the coil package and, thus, the magnetic field in relation to the die.

The suitable positioning of the magnetic field and the magnetic field strength can also help with the filling of the powder into the cavity, allowing the powder to be 'sucked' into the cavity magnetically. This proven pressing technology thus provides ideal conditions for a powder-saving production of magnets, either as semi-finished products or very precisely near net-shape.

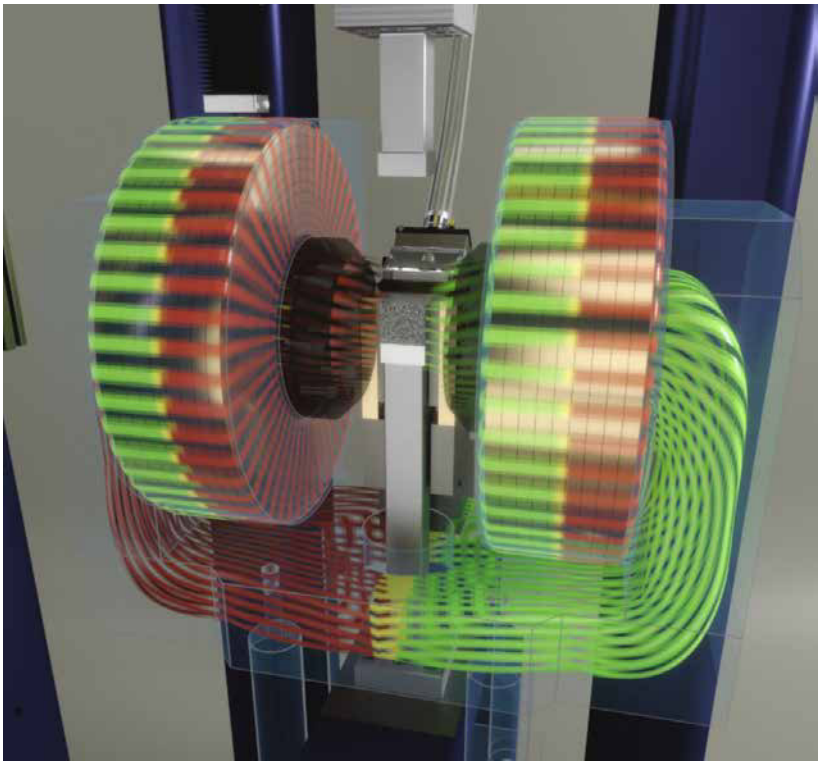

Fig. 4 Pressing in a transverse field realised with two vertical magnetising coils (Courtesy DORST Technologies)

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Pressing in a magnetic field

The electrons and atomic nuclei of a solid body have magnetic dipole moments. Ferromagnetism is manifested when the magnetic moments of the electrons of neighbouring atoms interact and align in parallel or antiparallel once an external magnetic field is applied. Soft magnets are characterised by the fact that this polarisation only exists as long as the external field remains. In contrast, hard magnets and permanent magnets see polarisation remain even after the external field has been removed. All materials affect a magnetic field to some extent when introduced into it. The magnetic moments of the electrons in the material interact with the external field, causing the material to become polarised. This polarisation can only be cancelled by a field of opposite orientation, an alternating field of decreasing strength, or heating it to a temperature higher than the Curie temperature of the respective material.

Permanent magnets with crystalline anisotropy (ferrite, SmCo, NdFeB) are pressed within a magnetic field, then sintered, processed, and finally magnetised. When pressing in a magnetic field, a distinction is made between transverse field pressing and axial field pressing. Selecting the appropriate magnet press requires determining the shape and maximum size of the magnets to be pressed.

Pressing in a transverse field is realised with two vertical magnetising coils (Fig. 4). The process should be evaluated in terms of required tool optimisation and ease of part removal. When pressing in an axial field, coils are positioned horizontally. Solutions exist with either a single coil or a pair of coils, depending on the desired uniformity of the magnetic field for pressing. Throughout the compaction process, the magnetic field may be turned on or off, with strength adjusted according to specific requirements.

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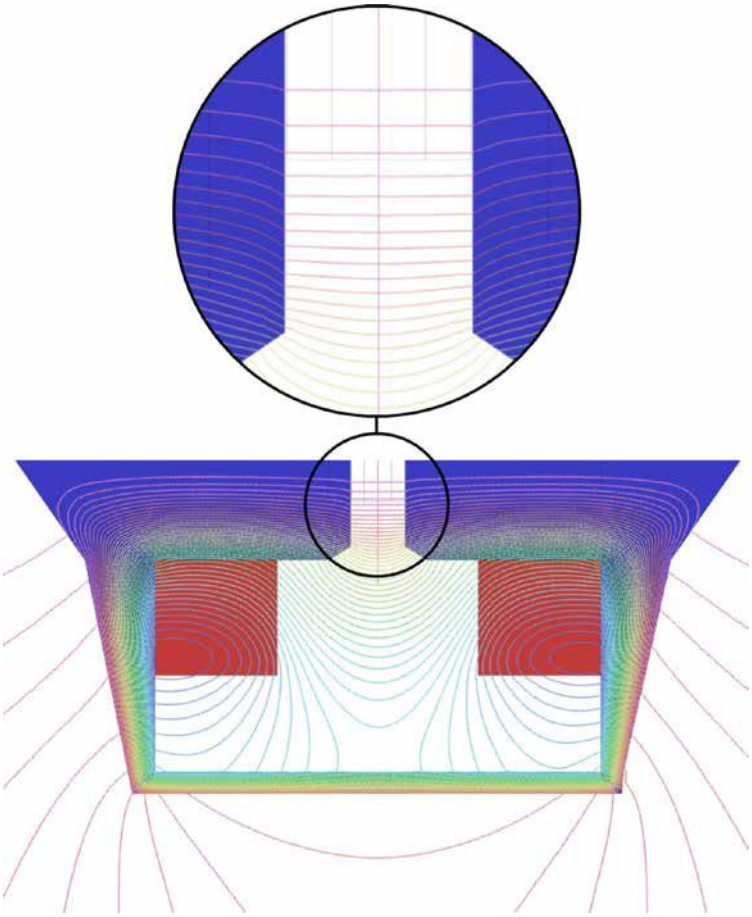

Fig. 5 Homogeneity of a transverse field for optimal particle alignment (Courtesy DORST Technologies)

> *"To achieve the best particle alignment, it is crucial to generate a high magnetic flux density in the powder column within the cavity. This calls for a precisely engineered magnetic circuit capable of delivering the required high flux densities."*

Coil, yoke and rectifier design

The coil, along with the power electronics that actuate it, form the core functional unit of a magnet press. There are essentially two different design versions for the coil: the transverse and the axial. As their names suggest, the field lines of the former are transversal, meaning they run at right angles to the pressing direction, while the latter's are axial, running parallel to it. Where the magnet geometry permits, the transverse coil is to be preferred since it allows for a slightly better alignment of the particles.

The coil's primary function is to align the extremely small powder particles in a single direction along the magnetic field lines. Additional tasks include providing magnetic support for the filling process and the subsequent demagnetisation, which facilitates the handling of the pressed parts.

To achieve the best particle alignment, it is crucial to generate a high magnetic flux density in the powder column within the cavity. This calls for a precisely engineered magnetic circuit capable of delivering the required high flux densities (Fig. 5).

DORST Technologies leverages its extensive experience in magnet production and utilises simulation tools to optimise coil design. The company collaborates closely with production and development partners due to the deep knowledge required in power electronics, cooling, and coil manufacturing (power electronics are based on state-of-the-art technology, ensuring safe, precise, and highly dynamic regulation of the current and, therefore, the magnetic field of the coil). The compact coils used are designed to achieve very high magnetomotive forces. Their efficient cooling provides a long service life, thereby accommodating diverse pressing and magnetising cycles.

Inert enclosure and monitoring

Depending on the material being processed, it may be necessary to remove atmospheric oxygen from the press area. Typically, oxygen content in air is around 21% at sea level, but this is too high a value for the production of NdFeB magnets, as the powder is highly reactive and can even catch fire due to oxidation. Therefore, the amount of atmospheric oxygen must be reduced to a minimum, depending on the material and application. This is achieved by creating an inert gas atmosphere within the machine's gas-tight safety device. Nitrogen is commonly used as a shielding gas, though noble gases such as argon are also suitable. The oxygen content is

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monitored in a two-step procedure using appropriate sensors, ensuring that the magnet press can only begin production once the oxygen levels have dropped below the required threshold. To reduce costs, it is important to keep the volume of exchanged air as small as possible and position the enclosure close to the press area (Fig. 6).

Gloveboxes enable the operator to reach into the enclosure through gloves, eliminating the need to open the inert enclosure for every manual intervention. Still, any operating staff must also remain protected when the press area is open or access is required. This is achieved by monitoring the atmospheric oxygen levels in the press area, admitting air and enabling the doors to be opened only after human-safe levels are reached.

Part handling, cleaning, and tool changes

Pressed magnets can be removed using various methods, starting with a magnetic pulse that demagnetises the exposed magnet to the level of individual magnetic domains – a process that doesn't affect macroscopic grain alignment. After mechanical processing and sintering, the magnets are remagnetised. Removal methods include chutes, linear axis transfers to conveyor belts, or robotic systems such as six-axis or Scara robots.

Residual powder is often removed magnetically, with the pressed magnets passing through an appropriate magnetic field after being extracted from the cavity. In this case, a six-axis robot is an efficient solution, combining part removal and magnetic cleaning in one process.

DORST Technologies offers simple solutions by transferring parts through an airlock to the customer's automation system. If desired, magnets can be placed onto sintering trays or in sintering boxes right after cleaning. The company has included various solutions in its FLEXCELL programme.

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Fig. 6 Inert press enclosure and oxygen monitoring system (Courtesy DORST Technologies)

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Fig. 7 Dorst EP30MAG press for precise permanent magnet production (Courtesy DORST Technologies)

"Regulating the magnetic field in the press area supports the filling process by ensuring precise magnetic alignment of particles during compaction and the necessary demagnetisation of the pressed magnets before they are released from the cavity..."

The EP30MAG press

The EP30MAG servo-motorised CNC press is a highly flexible and innovative press with a pressing force of 30 tonnes, specifically designed for the production of permanent magnets (Fig. 7). This press opens up entirely new possibilities for the quality of the magnets, achievable through ultra-precise regulation of a homogeneous magnetic field for powder compaction. The inert safety device is closely monitored to ensure precise control and reduced oxygen content in the press area.

Regulating the magnetic field in the press area supports the filling process by ensuring precise magnetic alignment of particles during compaction and the necessary demagnetisation of the pressed magnets before they are released from the cavity for further processing.

The press frame features a four-column design with a lateral arrangement for the removal and filling systems; a front/rear arrangement is also possible as an alternative. The press' movable crossheads, which serve as precise locating elements for the upper and lower T-pieces, are guided along the press columns by high-precision linear systems. These T-pieces form robust connections between the crossheads and the tooling, ensuring accurate force transmission and alignment during pressing operations. The press operates with a die withdrawal system, ensuring efficient removal of the tooling after each pressing operation.

The press features three position-controlled drives, with the option of closed-loop force control on the upper main drive:

- upper main drive
- lower main drive (die)
- filler drive 1

The press is operated by a movable operator terminal. The company's Intelligent Program Generator (IPG) supports programming to ensure maximum operator convenience. The open- and closed-loop controls are achieved through two independent PC systems, with the DORST Control System (DCS) managing the closed-loop control of the axes and the DORST Visualization System (DVS) handling the visualisation.

The press includes a standard powder filling system, optimised and adaptable to each specific application. Solutions for gravimetric weighing are also available.

The parts are pressed in a homogenous, adjustable transverse field generated by two vertical coils. The coils are firmly attached to the die. The homogeneity of the generated magnetic field allows for a filling height of up to 100 mm

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at a standard tool installation width of 100 mm. At a compaction factor of, for example, 2.2, the pressed magnets will have a height of up to 45 mm. Any tool or material brought into a magnetic field influences this field. Simulation software is available to support customers when designing applicable tools and selecting suitable materials.

The coil's arrangement allows the parts to be pushed off onto a chute. The magnets can also be transferred through an optional airlock to a customer automation system docked to the press. Three sides of the safety device are equipped with 'double glove' modules, which consist of gloves and safety locking devices that prevent the operator from reaching into the danger area, eliminating the need to open the inert safety device for routine tasks.

The press has a gas-tight press safety device that meets CE conformity standards and is suitable for an atmosphere of nitrogen (N_2). Inspection windows provide an excellent view into the machine's interior from the operator's side, the rear, and the sides. A separate frame outside the inert enclosure serves as a connection point for the powder storage hopper of a filling device, with the frame designed to be detached from the press using a pallet truck for setup and maintenance purposes.

The safety device is equipped with gas-tight cable bushings and media feed-throughs for the nitrogen and cooling water supply. Two redundant oxygen sensors monitor the residual percentage level of oxygen content, while an additional oxygen sensor controls the ppm range. An intake air fan enables rapid air ingress, enabling the safety device to be quickly de-inerted. Electrically actuated vent flaps allow for connection to a workshop suction or venting system, while pressure relief valves ensure a consistent setting of the overpressure.

Conclusion

DORST Technologies offers both standard and custom solutions for magnet pressing, with press forces ranging from 15-1,600 tonnes. With over forty years of experience, the company has developed a strong understanding of the various requirements of magnet production. The EP30MAG serves as a robust standard press option designed to meet a wide range of application requirements. DORST Technologies focuses on refining its systems to support consistent production while meeting rising expectations for energy efficiency and quality. This enables improved operational performance and reduced environmental impact – priorities that align with the green revolution driving increased demand.

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