A Few Advantages of Injection Molded Magnets

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At Tengam Engineering, Inc., we believe the magnet deserves attention early in the design process. Its material, shape, orientation, and manufacturing method influence how efficiently the application functions, how accurately its components fit together, and how economically it can be produced. In today's environment, understanding these factors, the supply chains for raw materials, and total system cost is paramount during the early design of your product.

Magnetic strength matters. So do electrical losses, airgaps, mechanical integrity, assembly methods, and production cycle times. Those considerations are where injection molded (injection bonded) neodymium-iron-boron (NdFeB) and samarium-iron-nitride (SmFeN) materials become particularly interesting.

We have been manufacturing injection molded magnets in Otsego, Michigan, for more than fifty years. That experience has taught us to look closely at what the complete application

requires and to bring magnet design and manufacturing into the discussion while engineers still have room to make useful changes.

Injection molded magnets combine magnetic powder with an engineered thermoplastic binder, commonly polyamide or polyphenylene sulfide (PPS). These compounds can be molded into rings and complex geometries, including components that are subsequently integrated with shafts, carriers, and other parts. The powder supplies the magnetic properties. The binder and molding process create opportunities in geometry, electrical resistance, and mechanical integration.

One of the most useful advantages of injection molded magnets is their significantly lower eddy current loss. With suitable materials and operating conditions, these losses can be negligible.

A permanent magnet can generate heat when changing magnetic fields induce circulating electrical currents within it. In a motor, slotting effects, winding harmonics, and inverter ripple create changing fields that the rotor magnets experience. The resulting losses consume energy and add heat in a location that can be difficult to cool.

The polymer in an injection molded magnet increases electrical resistivity and restricts the conducting paths available to those currents. Compared with an electrically conductive, dense sintered magnet, the reduction in magnet heating can be significant and should be evaluated carefully during the design process. Low electrical conductivity is one practical advantage of the injection molded magnet.

Less heat generated in the magnets can improve the thermal margin and reduce the need for magnet segmentation, a common practice in many motor designs. Careful rotor design must also account for shafts, sleeves, and other conductive components that can contribute to overall losses. The engineering objective is to reduce the heat produced throughout the assembly.

Airgap control provides another opportunity.

The airgap has a direct effect on the magnetic circuit. A smaller effective gap can improve magnetic coupling and help the designer obtain more useful performance from the available magnet material. Achieving that gap consistently requires control of dimensions, concentricity, and assembly variation.

Injection molding produces the magnet’s geometry from a precision injection mold. With suitable tooling and process control, this provides repeatable dimensions and can eliminate much of the subsequent machining. Shrinkage must be characterized and compensated for early in development, just as it must with any precision molded component.

A continuous molded ring can remove the individual placement and adhesive-thickness variations associated with assembling separate magnet segments. Molding around a properly located shaft or carrier can further reduce the number of interfaces contributing to variation.

Our engineering experience shows that these capabilities can support tighter airgaps when the finished rotor's dimensions and operating behavior are controlled.

The clearance still must accommodate bearing tolerances, runout, temperature, moisture exposure, and centrifugal growth. Any retaining sleeve or polymer covering also contributes to the effective magnetic gap. Precision molding gives the designer useful control, and the complete rotor determines how that control can be used.

Injection molding also makes Halbach orientation practical in a single magnetic component.

A Halbach pattern progressively changes the magnetization direction around a ring. This concentrates flux toward the working side and reduces the field on the opposite side. Depending on the motor design, the result can include a more sinusoidal airgap field and reduced dependence on rotor back iron.

With anisotropic material, a designed magnetic field aligns the powder while the molding compound is still mobile. Once the polymer solidifies, the preferred orientation is fixed in situ. Depending on the material and the field achieved during molding, subsequent magnetization may be needed to achieve the required permanent magnetic field.

That is a considerable manufacturing advantage. The production part can contain the desired orientation in one continuous ring, reducing the handling and complicated positioning required for a segmented Halbach assembly.

The injection molding tooling must be carefully constructed to be effective. Anisotropic SmFeN requires a suitable aligning field during molding, and nearby shafts, yokes, and mold components influence that field. Where the required magnetic performance can be achieved with an isotropic grade, the magnetic pattern can be established after molding. This can simplify tooling and provide a more cost-effective solution. Either approach requires properly designed magnetic tooling. Once developed, that tooling makes the pattern repeatable in production.

The mechanical advantages are equally useful.

The polymer matrix provides compliance, while the molding process allows locating and mounting features to become part of the magnetic component. Continuous geometry and integrated interfaces can simplify handling and reduce the number of joints in an assembly. These are highly filled composites, so their mechanical behavior must be evaluated using the actual compound rather than the properties of an unfilled plastic. Mechanical retention must also account for operating temperature, creep, fatigue, and environmental exposure.

Lower density also reduces centrifugal loading and rotational inertia when geometry and speed are held constant. Mechanical engagement with a shaft or carrier can be incorporated into the

magnet or created through a secondary injection molding process, giving engineers another way to transfer torque and retain the magnet.

These manufacturing advantages also extend to interior permanent magnet, or IPM, assemblies.

For suitable IPM designs, magnetic compound can be molded directly into cavities within the rotor core. This allows the magnet geometry to follow the magnetic and mechanical requirements of the rotor while reducing the handling and insertion of individual magnets. SmFeN and NdFeB materials can be molded directly into IPM magnet assemblies with very fast cycle times. Developing the material, rotor geometry, tooling, and automation together early in the process creates opportunities for repeatable, high-volume production with fewer separate assembly operations.

The molding cycle is one part of the production process. Loading, unloading, magnetization, and inspection must also support the required production rate. Bringing those operations into the design discussion early helps turn a promising magnetic concept into an assembly that can be manufactured consistently.

As with many engineering challenges, there are tradeoffs. The polymer occupies volume that would otherwise contain magnetic material, so injection molded magnets generally provide lower remanence and energy product than dense sintered NdFeB. The design must account for that difference. Suitable geometry, orientation, and manufacturing choices can still produce a successful application.

Our view is that the evaluation should include the complete motor, considering useful airgap flux, magnet heating, rotor mass, mechanical retention, assembly variation, and manufacturing cost. A lower-loss material, a well-controlled airgap, a tailored orientation, and a rapidly molded IPM assembly can each contribute to a better overall result.

At Tengam Engineering, Inc., we encourage engineers to bring us into that discussion early. Define the field the application needs. Consider the operating conditions. Develop the magnet geometry, orientation, and manufacturing process together.

THINK MAGNETS FIRST.

#SmFeN #PermanentMagnets #ElectricMotors #MotorDesign #IPM #Magnetics #AdvancedManufacturing #Engineering #Tengam

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