EXPERT REPORT

MS-Schramberg: Manufacturing plastic-bonded, injection-molded rotors economically in large quantities

Rotors for cooling water pumps

Electrical cooling water pumps are becoming ever more important: Because they are not driven by an engine via belts like mechanical pumps, they optimize fuel consumption, thus reducing the emissions from combustion. In hybrid and electric vehicles, they cool the fuel cell stacks, the battery and the electronic components. They also ensure that the interior heating works properly. A core component of the cooling water pump is the 'drive rotor with impeller'. MS-Schramberg, developer and producer of magnet and system solutions, has optimized the assembly to customer requirements and introduced production for very large quantities.

The demands of rotor assemblies in cooling water pumps are enormous. They need to be resistant to a wide range of cooling media and extreme temperature differences from -40 to +150 °Celsius. This means that they are repeatedly exposed to temperature shocks. To avoid vibrations and thus the generation of noise, only minimal imbalances are permitted. For economical production, the magnetic materials used should also be as resource-saving as possible, and rare earth materials should be avoided – or at least reduced – as far as possible. This is because rare earth materials are subject to strong price fluctuations. Almost 97 percent of rare earth materials come from China. This creates dependencies that manufacturers want to avert.

One answer to this is provided by plastic-bonded, injection-molded magnetic rotors connected to and mounted on an impeller. This assembly that forms the heart of the pump can be produced economically in extremely large quantities using multicomponent injection molding technology. The production technology can be supplemented with other processes, such as the feeding of bushes or axles and the subsequent packaging. The high degree of automation enables high quality standards to be achieved.

The right magnetic compound

First, it is important to select the optimal magnetic compound for the respective application. Since the magnetic material must be chemically resistant and replace rare earth materials, hard ferrite (HF) is ideal. MS-Schramberg develops and produces these compounds tailored to the respective product and process requirements and uses multicomponent injection molding technology for the further processing of them. Magnetic systems are integrated in the tools in order to align and magnetize the magnetic material with multiple poles during the process. The compound and process can be optimized to the magnetic performance requirements.

This usually requires the components to have large wall thicknesses, but can have an unfavorable effect on quality, as sink marks and shrinking can occur. It can also adversely impact the magnetic alignment. Large wall thicknesses also require long cycle times that have a negative effect on the cost-effectiveness of the injection molding process. Production therefore takes place in several stages: The rotor is divided into an inner and an outer ring. The components for the inner and outer area of the rotor are manufactured in separate cavities in the multicomponent injection molding tool. This approach shortens the cycle times for the injection molding process by almost half. Higher balancing grades and lower component tolerances can also be realized. In addition, in the separate manufacturing steps, the magnetic alignment is also improved – this increases the magnetic performance of the rotor.

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Reducing rare earth materials

The trend is towards ever more compact cooling water pumps with even higher capacities. This is not usually possible to implement without rare earth materials. The multi-stage injection process and the optimized ratio with hard ferrite make it possible to minimize the use of rare earth compounds. To do this, MS-Schramberg first injects the inner rotor area with an HF compound, then the outer area of the rotor close to the stator – with neodymium-iron-boron (NdFeB), for example (Figure 1). To keep the use of this rare earth material as low as possible, the principle of magnetic superpositions is suitable. Here, the magnetic fields add up ideally. An example: A four-pole rotor is split. The flux density generated by the inner magnet is 42 millitesla (Figure 2 to Figure 4) and that of the outer 105 millitesla. (Figure 5 to Figure 7). Apart from small rounding errors, the sum results in a flux density of the complete rotor of 147 millitesla (Figure 8 to Figure 10). Both complement each other ideally with their generated magnetic flux densities. Thanks to the magnetic superposition principle, material - i.e., rare earth material – can be saved and the process optimized. NdFeB is only used in the outer area since the higher remanence and coercive field strength here effectively support the effect. The magnetic superposition means that the inexpensive hard ferrite compound continues to contribute to the increase in performance.

Figure 1. The inner and outer areas of the assembly are manufactured in separate cavities inside a multicomponent injection mold.

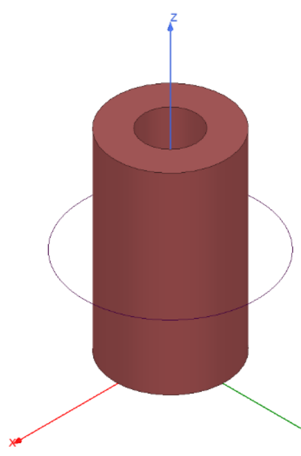


Figure 2. The inner area of the rotor

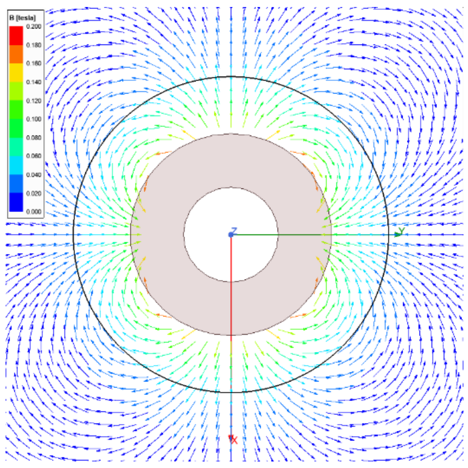


Figure 3. The FEM model shows the course of the flux lines

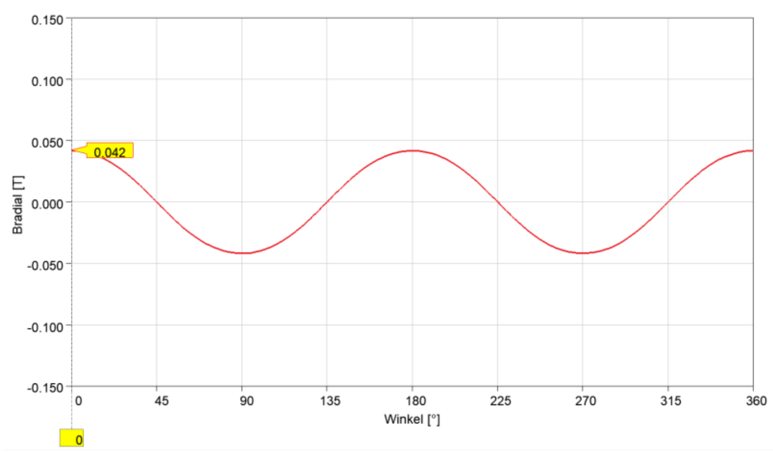


Figure 4. The flux density of the model with a radius of 3.3 millimeters is about 42 millitesla.

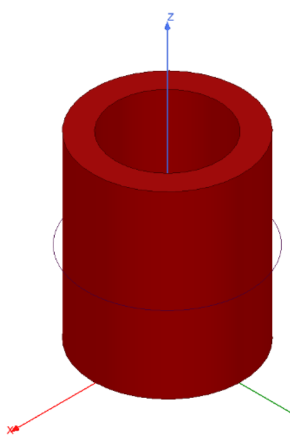


Figure 5. The outer area of the rotor

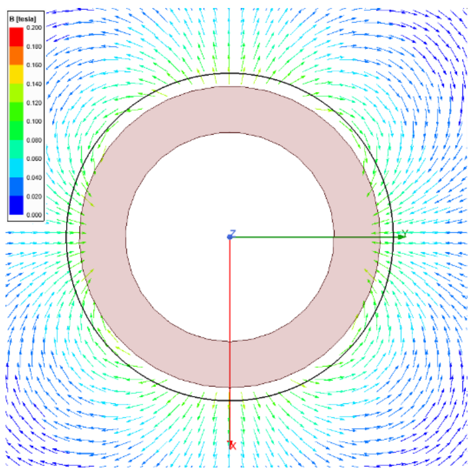


Figure 6. The FEM model shows the course of the flux lines

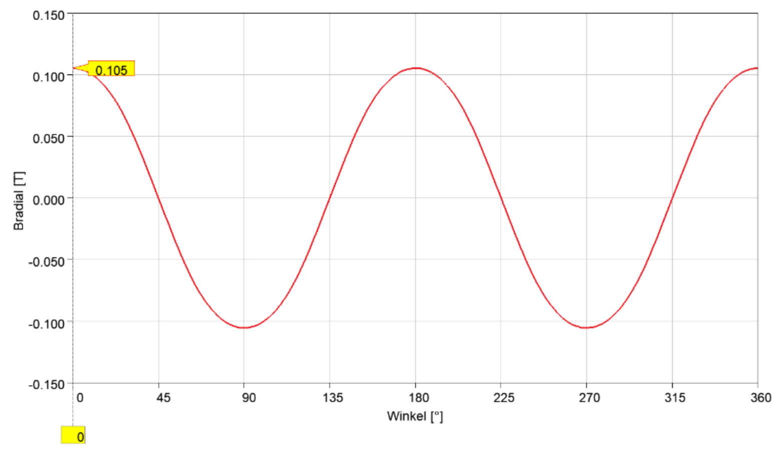
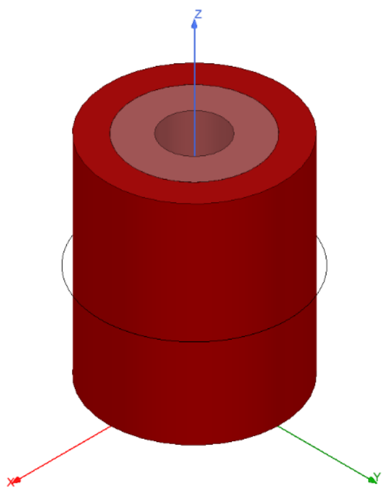
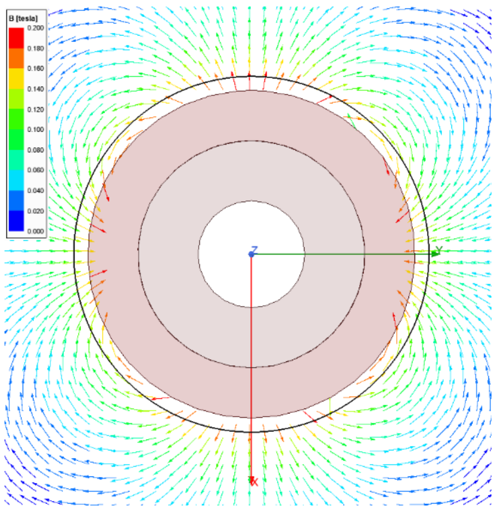


Figure 7. The flux density is about 105 millitesla





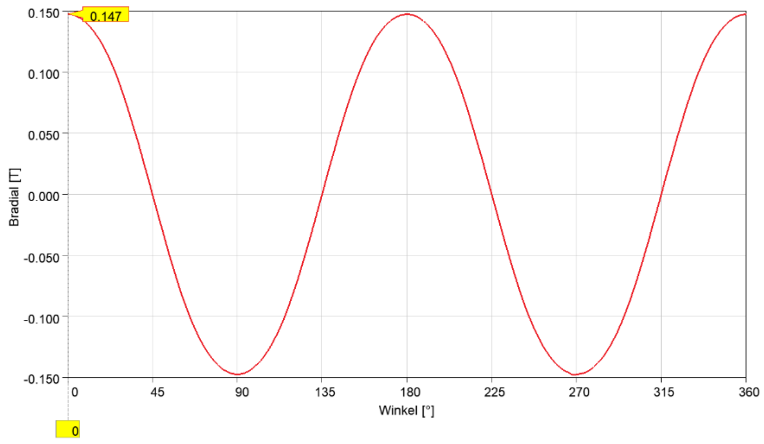


Figure 8. The model of the complete rotor

Figure 9. The course of the flux lines in the complete rotor

Figure 10. The flux density of the complete rotor is 148 millitesla. The inner and outer areas complement each other ideally with their generated magnetic flux densities.

Cost-effective replacement of laminated cores with hard ferrite compound

The inner areas of the magnets in larger rotors are often made of laminated cores in order to reduce the wall thickness. The laminated cores act as magnet carriers and optimize the magnetic circuit. The principle of superposition can also be applied here: This means that either the performance of the rotor can be further increased, or the laminated core can be saved with the same performance. In a specific application, a conventional laminated core and isotropic NdFeB with a volume of 3.22 cubic centimeters are installed in the rotor. If hard ferrite is now used instead of the laminated core, the proportion of rare earth material can be reduced by up to 30 percent. Because the material costs of hard ferrite compounds are three times less expensive than the laminated core otherwise required, this offers a significant cost advantage. Also, the lower specific density of the hard ferrite compound makes it lighter than steel.

Rotor version	Components	Compound volume	Savings
Conventional with laminated core	NdFeB-p isotropic Ø18.5xØ14xH28 mm Laminated core Ø14x Ø8xH28 mm	3.22 cm³	
New with HF-p anisotropic inside instead of a laminated core	NdFeB-p isotropic Ø18.5xØ15.5xH28 mm HF-p anisotropic Ø15.5x Ø8xH28 mm	2.24 cm³ 3.88 cm³	30 % less NdFeB isotropic Material costs of HF-p compound are also 3x less expensive than the laminated core required in this example

The basis for these processes at MS-Schramberg are calculations and simulations relating to the product, tool, and process. These also include the magnetic field technological simulation for designing the magnetic circuit as well as the structural analysis and thermal analyses, and Computational Fluid Dynamics (CFD) that consist of flow and thermal analysis as well as fluid-solid interaction. Virtual Molding can be used to continue to analyze and optimize the tool and manufacturing process. It is also possible to calculate polymer melt flows in the injection molding process and predict the distribution of fillers in them. This means that customers always receive the ideal solution for their application.

Image source: MS-Schramberg

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About MS-Schramberg GmbH & Co. KG

MS-Schramberg GmbH & Co. KG – Magnet and system solutions – is one of Europe's leading manufacturers of permanent magnets and assemblies. For more than 50 years, the family business has stood for solution expertise and quality. Important success factors are a high level of professional competence, above-average commitment to training and further education, a high willingness to invest and intensive material and process development. In Schramberg in the Black Forest, around 500 employees develop and produce customer-specific items for companies in various industries around the world. Important branches of industry are automotive, heating and air conditioning, electrical and automation engineering as well as mechanical engineering. MS-Schramberg combines extensive know-how on shaping options and material characteristics in processes with state-of-the-art process and automation technology. Together with intensive cooperation and customer support, this creates the basis for innovative product solutions.

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