

# 3OMATEC

MORE THAN JUST MAGNETS



## 3 CASE STUDY

### Eddy Current

Management in a High-Speed Permanent Magnet Motor Generator

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3OMATEC  
MORE THAN JUST MAGNETS

 UNIVERSITÉ DE  
SHERBROOKE

 Exonetik

# Welcome

Developed by Bomatec International in collaboration with Exonetik and Sherbrooke University, this study evaluates patented Snakeline magnets as an effective solution for eddy current loss reduction in high-speed motor-generator applications.

Compared with conventional laminated and monolithic magnets, Snakeline technology demonstrates a compelling balance of electromagnetic performance, loss reduction, and manufacturing cost.

This case study was produced in 2021



## Armin Sejfic

Head of Engineering



# CASE STUDY

**“Permanent magnet motor optimization is our specialty.”**

Bomatec International, in partnership with Exonetik and Sherbrooke University, has developed a new magnet design for a high-speed motor-generator unit. As a means of eddy current management, Snakeline magnets, and the associated improvements in eddy current losses, have been studied against traditional laminated magnets and monolithic magnets, showing the advantage of Snakeline as low-cost solution. Additionally, the effect of differing fill fractions on the magnetic performance of the motor was also considered. The designed motor has been constructed and is now undergoing testing.

For size- and energy-efficient applications, radial flux motors have long been a preferred design geometry, especially as speeds run in excess of 100,000 RPM. Exonetik is looking to leverage their own proprietary magnet retention technology in this application to design a new generation of low-cost compact self-starting generators directly driven by high efficiency turbomachinery. Working toward this goal, Exonetik and their partners at the University of Sherbrooke have worked with Bomatec International Corporation to leverage their patented Snakeline design to help meet the cost and performance goals of this application.

## Permanent Magnet Rotor Design

The basics of the rotor design center around a classic twopole rotor with a Halbach configuration. The design goal is to generate 30 kW of power at 130,000 RPM while retaining a self-starting capability. As is common to all high-speed designs, eddy current generation in the magnet mass is a major source of heat generation and loss. The original design called for 2mm laminations on the magnet.

One of the major challenges with laminated magnets is cost. Laminated magnets have very low material yields due to the curf losses in slicing the magnet wafers, and typically less than 30% of the material input in the process is delivered as a finished magnet. Additionally, the process is inherently labor intensive, due the high amount of handling by skilled workers to create the magnet lamination stacks. These are the challenges the Snakeline magnet was meant to address.



## Optimizing Power, Conserving Budget

Snakeline magnets require far less labor to create, since there are only two additional, automated steps (cutting and filling) over a traditional monolithic magnet. Additionally, by eliminating the massive amount of slicing to create wafers, Snakeline magnets waste far less material than laminated magnets. The use of the serpentine cut in the magnet creates two dimensions of insulating lines in the part, which allow Snakeline magnets to provide higher frequency eddy current reduction at larger geometric scales than a laminated magnet.

## Comparing Eddy Current Losses

To evaluate this case, a series of finite element models were studied. The rotor was initially modeled as a complete object to validate what the smallest meaningful repeating unit was to optimize. Once the smallest repeating unit was identified, an optimal Snakeline pattern was determined, and then constructed again as a full rotor to compare against the other cases. The comparison in this study was a conventionally laminated magnet and an equivalently sized Snakeline magnet, as seen in Figure 1. For these simulations, we assumed an operating speed of 130,000 RPM, but also ran cases at 10% overspeed and underspeed.

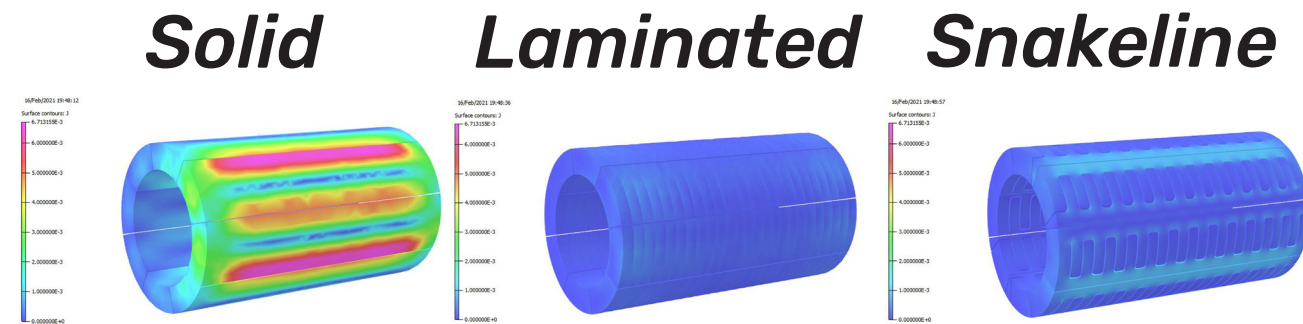
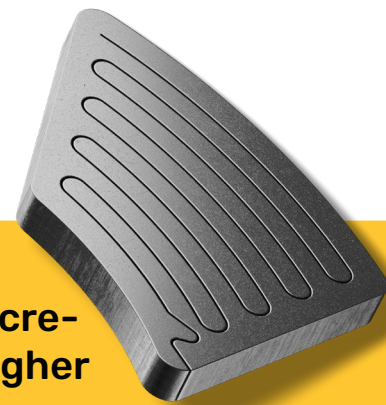


Figure 3: Simulated eddy current results for solid (left), laminated (center), and Snakeline (right) designs. All are plotted on the same color scale. The model uses a single stimulating coil, not shown.

**130,000 RPM**

30 kw of power at 130,000RPM

The Snakeline magnet's serpentine pattern creates insulating lines in the part, providing higher frequency eddy current reduction.



The case depicted is the worst-case model for eddy current generation, with the legs of the stimulating coil positioned over the solid edges of the magnet. Although the Snakeline magnet does have regions of higher current density, even the highest current density is an order of magnitude lower than in the solid magnet case. More importantly, the cut regions of the Snakeline design show similar eddy current inhibition to the laminated magnet case.

In addition to the visual plots shown, Table 1 shows the quantified results along with the calculated magnet volumes and estimated cost factors. For this analysis, the insulation layers in the segmented magnet were assumed to be 50 microns thick. Motor generator performance can be assumed to scale linearly with volume of magnet in the design.

## Summary of Eddy Current Loss Calculations

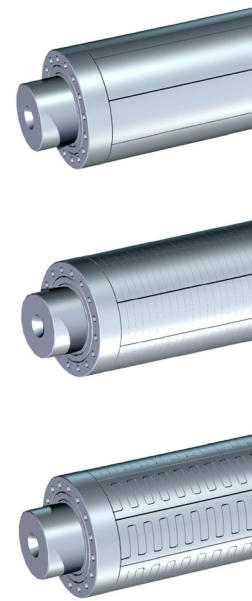
	Full Magnet (2027 mm <sup>3</sup> magnet volume)	2mm Segmented Laminated Magnet 25 Segments (1928 mm <sup>3</sup> magnet volume)	Snakeline Segmentation 25 "Segments" (1877 mm <sup>3</sup> magnet volume)
Speed (RPM)	Normalized Power Loss [%/Magnet]		
117,000	67.0%	7.7%	8.4%
130,000	82.7%	9.6%	10.3%
143,000	100.0%	11.6%	12.5%
Material input			
	3117 mm <sup>3</sup>	4207 mm <sup>3</sup>	3117 mm <sup>3</sup>
Cost Factor			
	1	15	1.3

"The key takeaways from this analysis are clear. The Snakeline magnet provides a design that competes very strongly with the laminated design in terms of raw performance and eddy current elimination at a fraction of the cost."

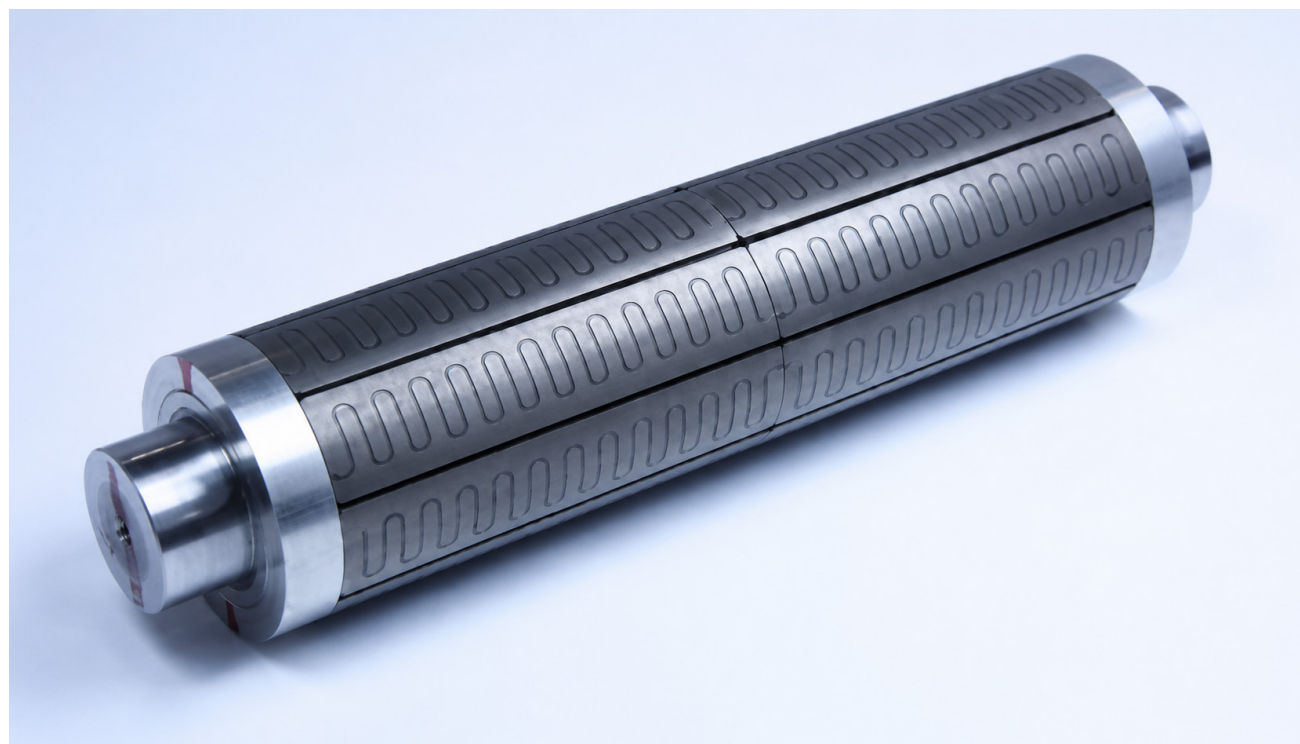
Philippe Scheuber  
Head of Sales

## Cost Advantages

The comparison between the Snakeline and the laminated magnet configurations becomes much more interesting when one begins to include the cost factors. Snakeline magnets are produced using industrial-precision wire EDM machines, which already have an enormous installed capacity base in the Asian magnet industry. The proprietary epoxy filling technique for the Snakeline is already mature and deployed on site with Bomatec's manufacturing partner. Because the Snakeline cut is made in a finished magnet, the process is simple to deploy across a design, and doesn't require a full re-construction of the process to produce the parts efficiently. Even more notably, the magnet lamination process converts a large amount of the starting material into grinding sludge. Assuming a standard slicing blade thicknesses of 0.5mm, the 2mm laminations require an additional 25% on the material input that never gets to the final product. This additional material is also tied to significant increases in manual labor, as magnet wafers are stacked and re-glued together. In contrast, the Snakeline magnet is produced with a single additional step and no additional input material, resulting in dramatic cost savings.



Renderings of design geometries.  
Solid (top),  
Laminated (middle), and  
Snakeline (bottom)

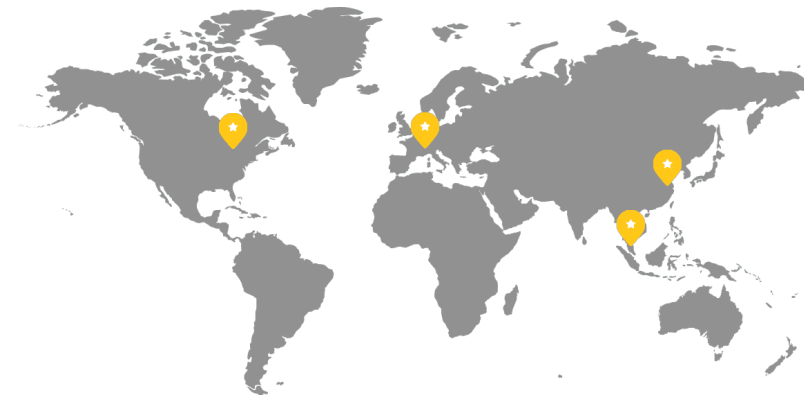


The high-speed radial flux design prototype is undergoing further testing before moving into volume production.

Initial prototypes of the Snakeline designs are now undergoing empirical validation to accompany this analysis. The powerful cost advantage coupled with the comparable performance benefit creates a compelling commercial case. This high-speed radial flux design usefully illustrates the powerful combination of benefits that Snakeline offers. More importantly, as more highspeed motors are deployed across a wider range of applications, the superior scalability and cost competitiveness of Snakeline technology enables efficiencies that are out of reach for solid and laminated samarium cobalt magnets.

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your reliable partner for high-tech products and innovation in magnet technology: in automotive, medical technology, Aero-space, e-mobility, renewable energies and factory automation.



Canada Switzerland Malaysia China

# From Switzerland to the world

## 1993

The founding of Bomatec

## 2014

Production in Malaysia

## 2018

Second production site in Malaysia

### MAGNETON

**BOMATEC has developed the unique MAGNETON** – a tool for calculating the magnetic force and flux of magnets according to your specifications. Enter a few specific parameters. The MAGNETON quickly provides a meaningful simulation of the magnetic field patterns and force components.

### SNAKELINE

**3D simulation for your design**  
Unsure if SNAKELINE magnets are right for your design?

We offer comprehensive 3D simulations when needed to easily compare performance data and ensure the best fit for your needs.

## Further Questions?

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