Concrete Binded Magnets for Large Power Inductors

The increasing demand for more and clean energy has led to a rising need for large inductive components. This poses a challenge to providing magnetics optimized for cost, size and performance. MAGMENT power inductors and transformers introduced at PCIM 2016 are based on a new technology for both a novel material and an innovative magnetic design. **Mauricio Esguerra, Magment Unterhaching, Germany**

The high demand has sparked the development of both improved magnetic materials (e.g., powder cores, amorphous), winding technologies (e.g., copper foil, flat wire) and optimized core geometries. This has yield a high refinement, pushing the limits of an otherwise conventional way of making inductive components. However, advancement in small steps maybe not enough to cope with the market expectations driven by the renewables revolution.

MAGMENT (MAGnetic ceMENT) power inductors and transformers are based on a patented concrete with magnetisable particles embedded in a cement matrix manufactured in a pressure-less process. Its features are (Figure. 1 and 2) permeability in the same range as powder core materials;

high DC-bias capability; saturation reached only at very high fields, very low core losses; high thermal conductivity to efficiently dissipate heat; and concrete-like mechanical robustness in a very broad temperature range.

Initial permeability	μ_i	@ 25°C		40 ± 10%
Flux density	B_{max}	@25°C, 25kA/m	[mT]	350
Curie-Temperature	T_c		[°C]	> 210
Resistivity	ρ	DC	[Ω m]	20
Density	γ		[kg/m³]	3750
Realtive core losses	P_V	@50kHz, 100mT	[kW/m³]	300
Specific heat	c_p		[J/kg K]	700
Thermal conductivity	λ		[W/mK]	3
Young's modulus	E_c		[MPa]	25 000
Compressive strength	f_c		[MPa]	20
Tensile strength	f_t		[MPa]	2

Figure 1: Technical data for MAGMENT MC40 material grade

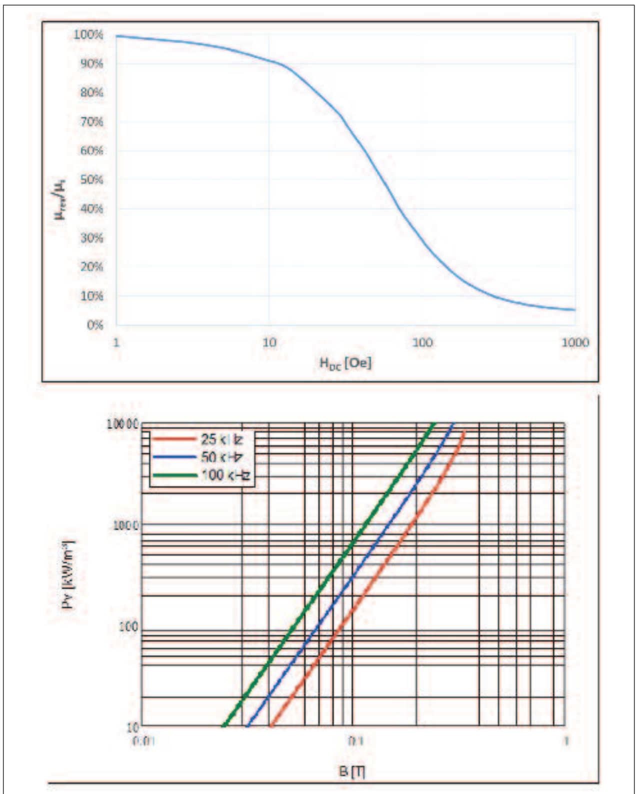

Figure 2: DC-bias vs field strength and specific core losses vs flux density

Wind and magnetic pour process

These unique and outstanding properties allow the design of rugged inductive components with a distributed air gap for minimized winding losses by completely surrounding the coil by the MAGMENT material. This ensures a complete magnetic filling of the available volume within the housing yielding maximum performance and cooling. As compared to the conventional manufacturing of winding cores and sealing with a potting material, the flowability of the concrete materials allow a "wind and magnetic pour" process, which goes along with absolute shape and size flexibility. This allows to both tailor components to minimize material utilization and to any given space constraints by a special magnetic design algorithm yielding lowest cost as compared to any other inductive technology.

Figure 3 shows an example for a MAGMENT inductor and Figure 4a

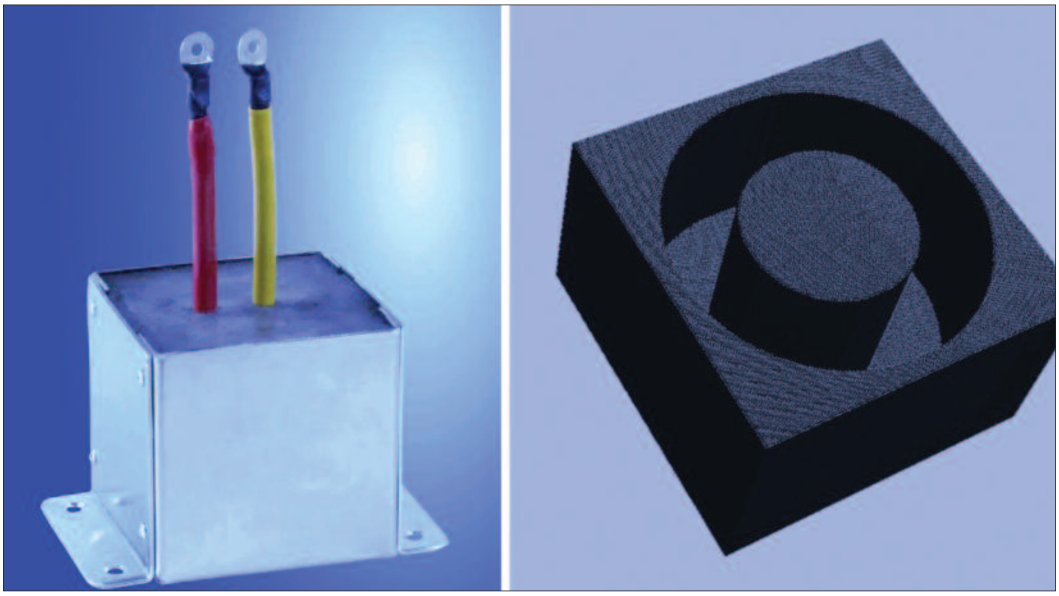

Figure 3: **MAGMENT inductor (left) depicting its magnetic material shape (right)**

Target parameters: inductance **L**, rated current **I**, resistance **R_{DC}**

Conventional	MAGMENT
DESIGN STEPS	
1. Select core shape (E, RM, U...)	1. Select/design coil former
2. Select core size (E25, RM8,...)	2. Layout of winding window
3. Select suitable coil former	3. Design housing
4. Layout wire in winding window	
5. Select housing	
6. Select potting material	
PROPERTIES	
Core sizes available only in steps (E55,E65,..)	No shape or size limitation
Limited size availability	
Stacking for simple shapes only (E, U, R)	
Winding filling factor limited	Winding 100% surrounded by magnetic material
Partial magnetic filling of housing	Potting material = magnetic material

Figure 4: **Comparison MAGMENT vs. conventional inductors**

comparison with a conventional inductor. The automated design process starts with the calculation of the MAGMENT inductor design parameters for given target parameters (inductance L, rated current I and DC resistance RDC). The design algorithm looks for the dimensions giving the lowest material cost and hence the most compact design. In case outer dimensions would be constrained by device space requirements, the algorithm would take this into consideration. Based on the output design parameters a suitable coil former is chosen and the winding laid out. The housing containing the inductor is then designed according to the outer dimension of the MAGMENT material block.

The resulting magnetic effective parameters (Figure 5) show the clear advantage over conventional inductors. As a general rule and due to the complete magnetic filling of the available space the ratio Ae/le is much larger for MAGMENT inductors. In a relative comparison of inductors with the same inductance and either the same (a) magnetic path, (b) cross section or (c) volume the MAGMENT inductors show always a superior performance (inductance, core and winding losses) as well as cost.

Beyond the technical superiority of the product as such, there are other aspects pertaining production and logistics. We have devised our production to have all inductor manufacturing processes under one roof. This allows to have short lead times and simplified stock holding of base materials allowing the quickest possible turnaround time from design-in to shipping.

Design case	l_e [mm]	A_e [mm²]	V_e [mm³]	No. of turns	Core loss [W]	Cost [€]
a	=	>	>	<	<	<
b	<	=	<	<	<	<<<
c	<	>	=	<<	<	<<

Figure 5: **Inductor parameters relative comparison MAGMENT vs. conventional for an inductor with the same inductance value and one effective parameter a) magnetic path, b) cross section, c) volume**