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Compounding MGRS recycled anisotropic NdFeB powder at KOL

Kolektor Mobility d.o.o.
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25.2.2026

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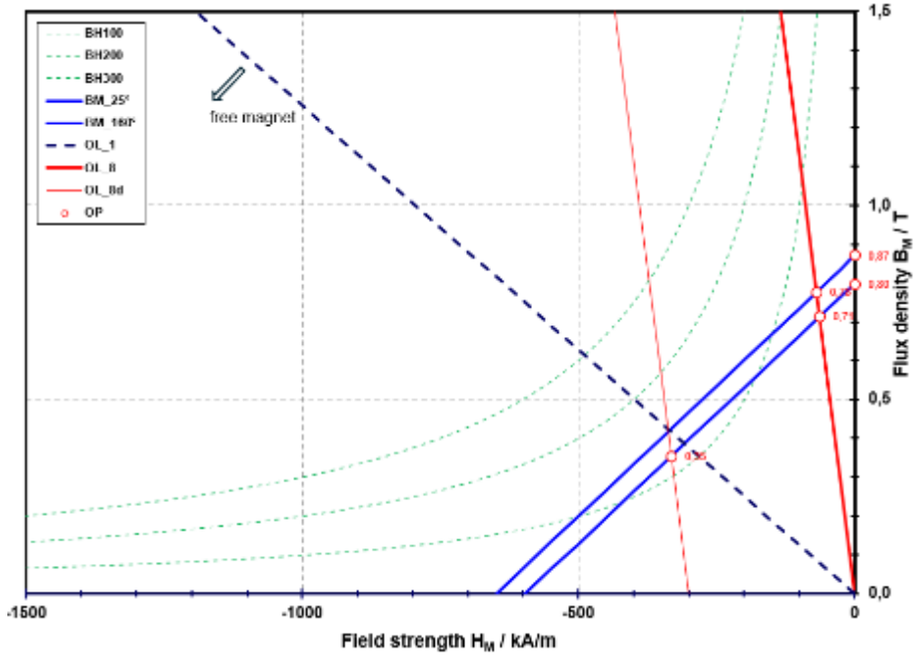
Target magnetic properties defined together with Schaeffler

- focus on magnetic performance; mechanical properties considered non-critical for this application
- magnet configuration:

- required magnetic properties:

remanence (25°C):				coercive force (25°C):					
Br =	0,869	T		Hcb =	649	kA/m		Hcj =	1617	kA/m
TKBr =	-0,06	%/K		TKHc =	-0,32	%/K		dT =	135	K



- temperature stability defined by low reversible temperature coefficients;
- target values serve as benchmark for MGRS-recycled anisotropic NdFeB compound development at KOL

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MGRS recycle powder characteristics, batch: C13A

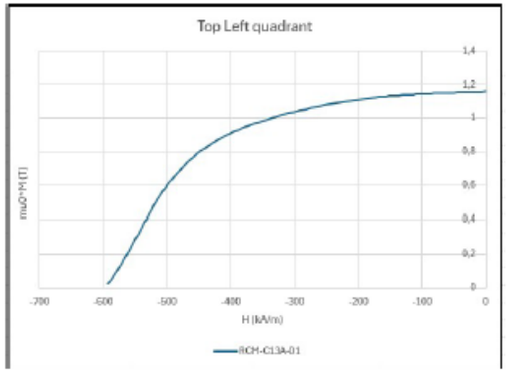
MagREEsource	MAGNET POWDER QUALITY CONTROL	Date : 07/07/2025

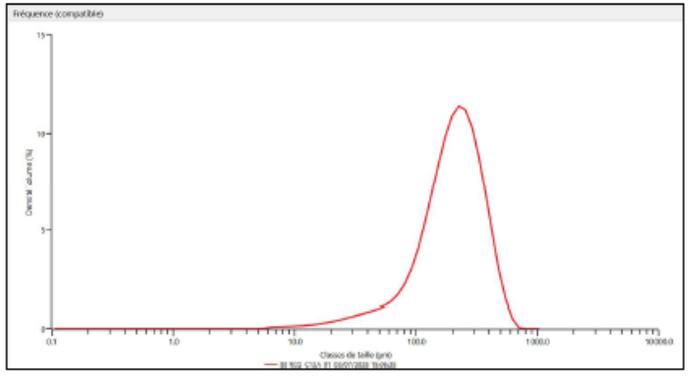
Description	Anisotropic NdFeB powder	Batch reference	C13A	Project number
Customer	Kolektor	Sample weight	2 batches of 4800 g each	SICAPERMA & PERMANET

MAGNETIC CHECKING					
Designation	Functions to control	Control method	Precision	Average	Comments
RCM-C13A-01	Remanent polarization $\mu_0 M_R$ (25°C) (T)	METIS pulsed magnetometer	0,005 T	1,16 T	powder aligned witin a resin prior to M(H) measurement
	Coercivity H_{cJ} (25°C) (kA/m)	METIS pulsed magnetometer	10 kA/m	597 kA/m	
	$(BH)_{max}$ (25°C) (kJ/m3)	METIS pulsed magnetometer		198 kJ/m3	

CHEMICAL CHECKING				
Designation	Functions to control	Control method	Results	Comments
RCL-C13A-01	Hydrogen contamination	LECO OH836	92 ± 2 ppm	
	Oxygen contamination	LECO OH836	943 ± 14 ppm	

GRANULOMETRY				
Designation	Functions to control	Control method	Results	Comments
RCG-C13A-01	Dv90 (µm)	Mastersizer 3000 +	382 µm	
	Dv50 (µm)	Mastersizer 3000 +	207 µm	
	Dv10 (µm)	Mastersizer 3000 +	81 µm	





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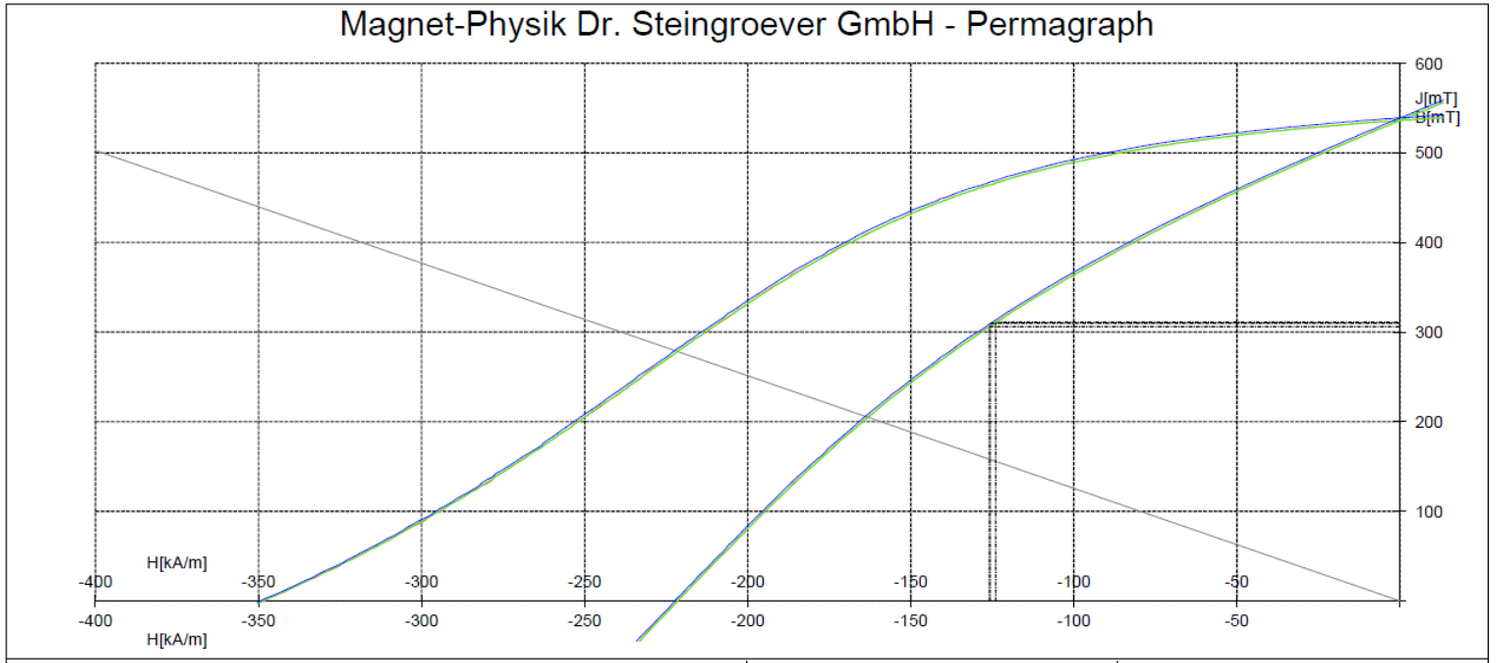
Compounding and injection molding at KOL

10 wt% of PA + 90 wt% of MGRS Nd POWDER (55 vol%) → standard recipe



	1	2	3	Average	
B_r	= 536.3	536.4	539.1	537.3	mT
$(BH)_{max}$	= 38.5	38.5	38.9	38.7	kJ/m³
H_{cB}	= 221.5	221.6	222.4	221.9	kA/m
H_{cJ}	= 348.9	348.5	349.6	349.0	kA/m
B_a	= 0.311	0.306	0.310	0.309	T
H_a	= 124	126	126	125	kA/m
J_k	= 0.483	0.483	0.485	0.484	T
H_k	= 108	108	109	108	kA/m
H_{max}	= 1354	1348	1353	1352	kA/m
T	= 23	23	23	23	°C
μ_{rec}	=			NaN	

Coil	: JH 26-1
$+I_{max}$	: 50 %
$-I_{max}$	: 50 %
dI/dt	: 13 %
Room temp.	: 22.4 °C
Spec. temp.	: 23 °C
Density	: 4.395 g/cm³
Diameter	: 9.9 mm
Area	: 0.7698 cm²

Date	: 26. 09. 2025
Customer	: Kolektor KFH
Operator	: Karla
Shape	: Cilindricni
Material	: Bonded rare earth
Ident materiala	:
Naziv	:
Delovni nalog	:
Šarza	:
Piece No.	: 2
Premer magneta	:
Density	: 4,395 g/cm3
Opombe	: PERMANET

	MGRS+PA12 1.batch
Vol% of MGRS powder	55
Density [g/cm³]	4,4
Br [mT]	537,3
Hcb [kA/m]	221,9
Hcj [kA/m]	349
BHmax [kJ/m3]	38,7

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Hypothesis of mag. properties

In case of using PPS (for T_{op} up to 150° C):

	Actual MGRS+PA12	MGRS + PPS hypothesis	Schaeffler requirements
Vol% of MGRS powder	55	~ 65	/
Density [g/cm^3]	4,4	~ 5,3	/
Br [mT]	537,3	~ 636	869
Hcb [kA/m]	221,9	~ 260	649
Hcj [kA/m]	349	~ 358	1617
BHmax [kJ/m3]	38,7	~ 45	140

Results show that with first test MGRS+PA12 we achieve 100% alignment of anisotropic particles. In case of higher vol% of MGRS powder (and higher density: 5,3 g/cm^3) we assume that we would achive 95% alignment and lower Hcj (due to internal friction).

With injection bonded magnet (MGRS recycle powder) we potentially can achieve max. 636 mT.

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MGRS recycle powder characteristics, second batch: C13B

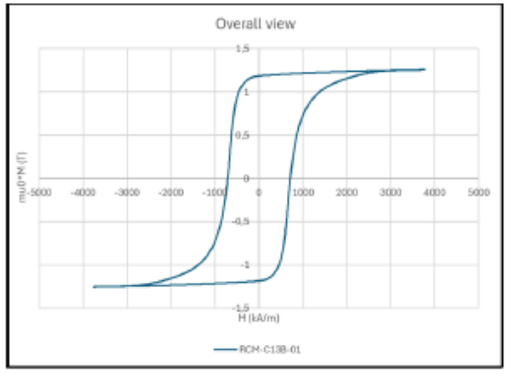
MagREEsource	MAGNET POWDER QUALITY CONTROL	Date : 13/10/2025

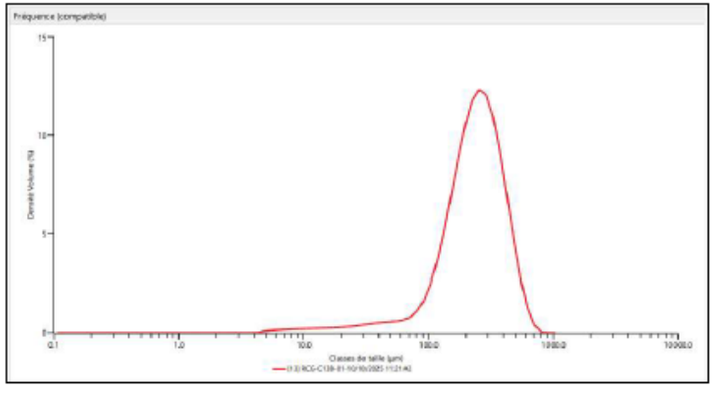
Description	Anisotropic NdFeB powder	Batch reference	C13B	Project number
Customer	Kolektor	Sample weight	8 kg	SICAPERMA & PERMANET

MAGNETIC CHECKING					
Designation	Functions to control	Control method	Precision	Average	Comments
RCM-C13B-01	Remanent polarization $\mu_0 M_R$ (25°C) (T)	METIS pulsed magnetometer	0,005 T	1,18 T	powder aligned witin a resin prior to M(H) measurement
	Coercivity H_{cJ} (25°C) (kA/m)	METIS pulsed magnetometer	10 kA/m	713 kA/m	
	$(BH)_{max}$ (25°C) (kJ/m3)	METIS pulsed magnetometer		229 kJ/m3	

CHEMICAL CHECKING				
Designation	Functions to control	Control method	Results	Comments
RCL-C13B-01	Hydrogen contamination	LECO OH836	43 ± 2 ppm	
	Oxygen contamination	LECO OH836	774 ± 18 ppm	

GRANULOMETRY				
Designation	Functions to control	Control method	Results	Comments
RCG-C13B-01	Dv90 (µm)	Mastersizer 3000 +	428 µm	
	Dv50 (µm)	Mastersizer 3000 +	241 µm	
	Dv10 (µm)	Mastersizer 3000 +	109 µm	





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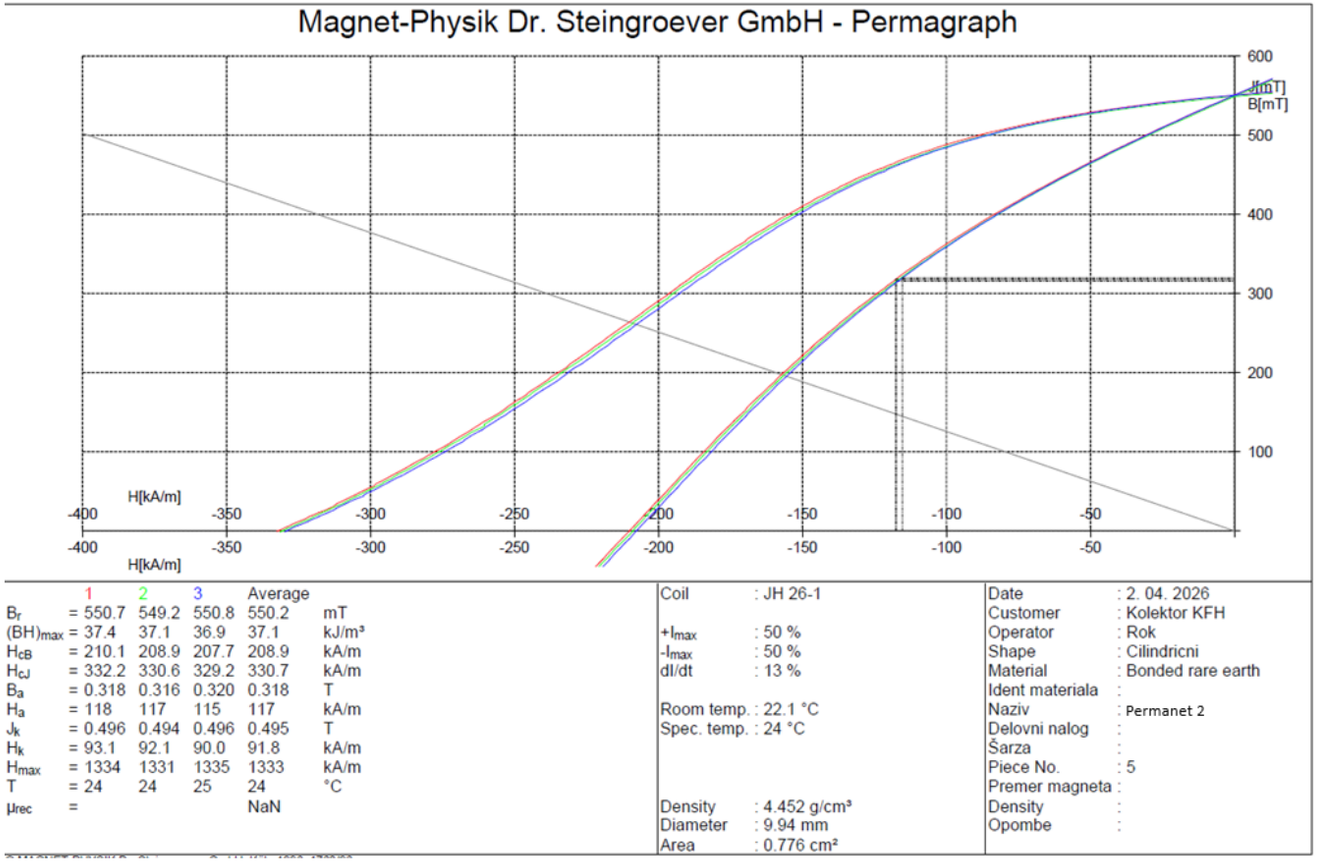
Compounding and injection molding at KOL (with second batch C13B)

10 wt% of PA + 90 wt% of MGRS Nd POWDER (55 vol%) → standard recipe



	1	2	3	Average	
B_r	= 550.7	549.2	550.8	550.2	mT
$(BH)_{max}$	= 37.4	37.1	36.9	37.1	kJ/m³
H_{cB}	= 210.1	208.9	207.7	208.9	kA/m
H_{cJ}	= 332.2	330.6	329.2	330.7	kA/m
B_a	= 0.318	0.316	0.320	0.318	T
H_a	= 118	117	115	117	kA/m
J_k	= 0.496	0.494	0.496	0.495	T
H_k	= 93.1	92.1	90.0	91.8	kA/m
H_{max}	= 1334	1331	1335	1333	kA/m
T	= 24	24	25	24	°C
μ_{rec}	=			NaN	

Coil	: JH 26-1
$+I_{max}$	: 50 %
$-I_{max}$	: 50 %
dI/dt	: 13 %
Room temp.	: 22.1 °C
Spec. temp.	: 24 °C
Density	: 4.452 g/cm³
Diameter	: 9.94 mm
Area	: 0.776 cm²

Date	: 2. 04. 2026
Customer	: Kolektor KFH
Operator	: Rok
Shape	: Cilindricni
Material	: Bonded rare earth
Ident materiala	:
Naziv	: Permanet 2
Delovni nalog	:
Šarza	:
Piece No.	: 5
Premer magneta	:
Density	:
Opombe	:

	MGRS+PA12 1.batch	MGRS+PA12 2.batch
Vol% of MGRS powder	55	55
Density [g/cm^3]	4,4	4,46
Br [mT]	537,3	552,7
Hcb [kA/m]	221,9	208,9
Hcj [kA/m]	349	336,1
BHmax [kJ/m3]	38,7	37,1

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Comparison 1st and 2nd batch with Schaeffler requirements

	Actual MGRS+PA12 1st batch	Actual MGRS+PA12 2nd batch	Schaeffler requirements
Vol% of MGRS powder	55	55	/
Density [g/cm^3]	4,4	4,46	/
Br [mT]	537,3	552,7	869
Hcb [kA/m]	221,9	208,9	649
Hcj [kA/m]	349	336,1	1617
BHmax [kJ/m3]	38,7	37,1	140

Overall, 2nd batch of deliered MGRS powder and prepared compound showed improved results in comparison with 1st batch, but still not meet Schaeffler requirements.

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Final automotive part (magnetic sensor for gas pedal) - in serial production

Besides regular reporting of material characteristics, we produced also final automotive part at Kolektor, which can be sold to final customer. We injected magnetic sensor for gas pedal and confirmed also final magnetic measurements on part. See picture of magnet sensor and magnetic measurements below:

KOLEKTOR	MERILNO POROČILO Meritve magnetnega momenta		
Koda:	5.212.36	Tip:	magnet
Ident TT:	348011	Kupec:	Bosch
Šarža mase		Meril:	Miha Kenk
Količina:	40 kosov	Pregledal:	Miha Kenk
D.N.:			
Opombe:	Merilna oprema: EF5 + Helmholtzova tuljava MS150 Testna masa: PERMANET EU MGRS powder+ PA12 (2. BATCH)		
Kraj in datum:	Idrija, 18.03.2026		

Ozn. vzorca	Magnetni moment z10 [μVs*cm]
A1_1	10,61
A1_2	10,82
A1_3	10,77
A1_4	10,92
A1_5	10,54
B2_1	10,58
B2_2	11,19
B2_3	10,96
B2_4	10,61
B2_5	10,83
C3_1	10,96
C3_2	10,77
C3_3	10,90
C3_4	10,61
C3_5	10,87
D4_1	10,96
D4_2	11,07
D4_3	11,65
D4_4	10,77
D4_5	11,68
D5_1	11,74
D5_2	11,45
D5_3	10,88
D5_4	10,72
D5_5	11,62
D6_1	11,78
D6_2	11,54
D6_3	11,67
D6_4	10,83
D6_5	11,64
D7_1	11,71
D7_2	10,77
D7_3	11,61
D7_4	10,96
D7_5	11,61
D8_1	11,61
D8_2	11,37
D8_3	11,48
D8_4	10,83
D8_5	11,57
MAX	11,78
MIN	10,54
AVG	11,13
STDEV	0,41

Conclusions:

Kolektor succesfully inject one of the serial product with recycled NdFeB powder from MGRS.

Product results meet all magnetic specifications required from customer.

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