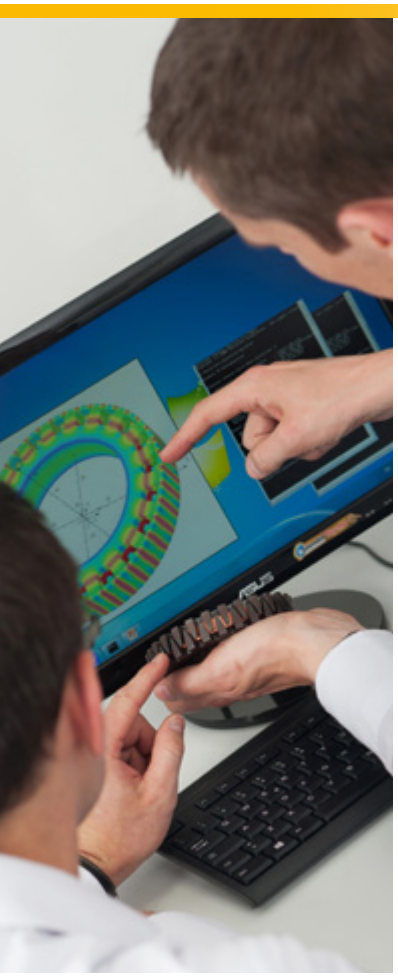
POWDER METALLURGY

Electromagnetic Applications




PM4EM® A GKN TECHNOLOGY

Powder Metallurgy meets Electro Magnetics

GKN ELECTROMAGNETICS

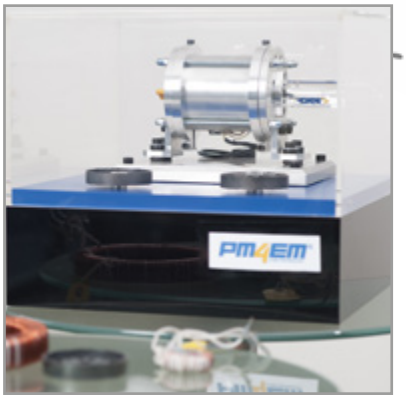
3D DESIGN FREEDOM

GKN's competence and experience offers excellent opportunities to create highly complex, 3-dimensional products in powder metallurgy. Even undercuts can be realised with the sophisticated compaction technology developed by GKN.
Due to this outstanding design freedom, innovative and more efficient product designs are feasible, in particular with soft magnetic materials.

GKN ELECTRO-MAGNETICS

Innovative and performance-oriented soft magnetic products usually require specific magnetic properties combined with an optimum of material utilization. Many solutions fail due to excessively costly operations caused by alternative manufacturing processes.

Powder metallurgy allows to produce optimized customer specific finished products for all industrial sectors at affordable costs.



SOFT MAGNETIC COMPOSITES (SMC)

Our technology for innovative, high performance electric motor components and high frequency applications.

SINTERED SOFT MAGNETICS

Our material and technology for complex structural parts in electromagnetic applications like linear and rotational actuation.

ENGINEERING

GKN's competence in engineering and design for best possible customer satisfaction.

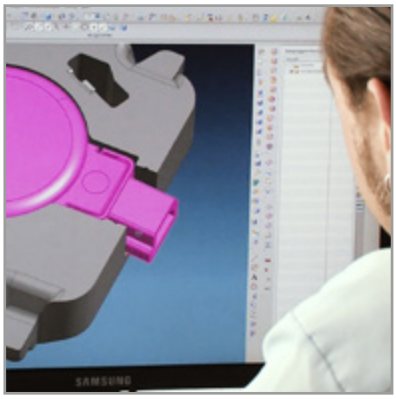
MATERIAL OVERVIEW

Engineered powders optimized to reach mechanical and magnetic properties.

ENGINEERING CAPABILITIES

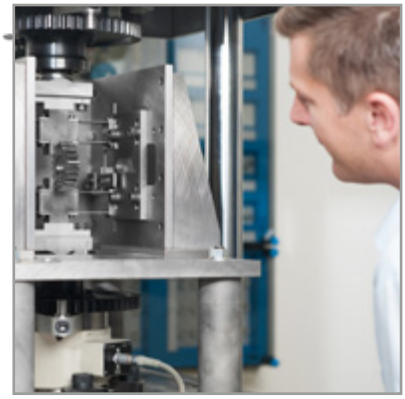
DESIGN FOR PM

- Exploit GKN's know-how as your partner in product development
- Technology-oriented design for cost efficient production
- Reduced development periods
- Added value due to integrated functionality



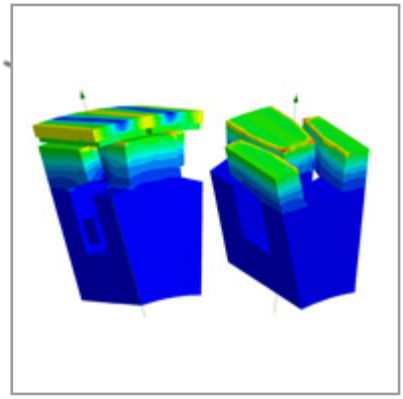
MATERIALS & ENGINE TEST BENCHES

- In-house materials test center for tensile testing, service life tests, elevated temperature testing, tribological testing
- In-house variable engine test bench for performance tests, long-run performance, thermal performance



SIMULATION

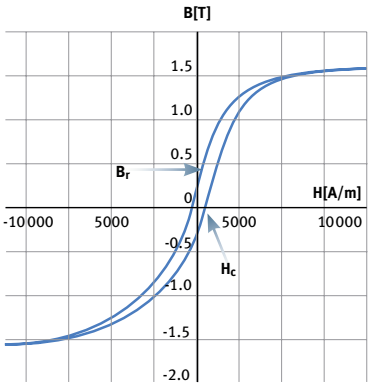
- Electromagnetic 3D simulation and system design
- Thermal simulation
- Structural mechanic simulation



METROLOGY

- B-H field meter
- Coercimat
- Resistance test

B-H HYSTERESIS CURVE



This curve describes a typical complete magnetizing cycle of a ring shaped test sample.
The magnetic field strength H is generated by a primary coil, the resulting induction or magnetic flux density B is registered by a secondary coil.

Essential parameters are the following:

B_r in [T]: Remanence, indicates how much "residual magnetism" remains in the core after the coil has been switched off.

H_c in [A/m]: Coercive force, represents the magnetic field that has to be built up by the coil to de-magnetize the core (B = 0 T).

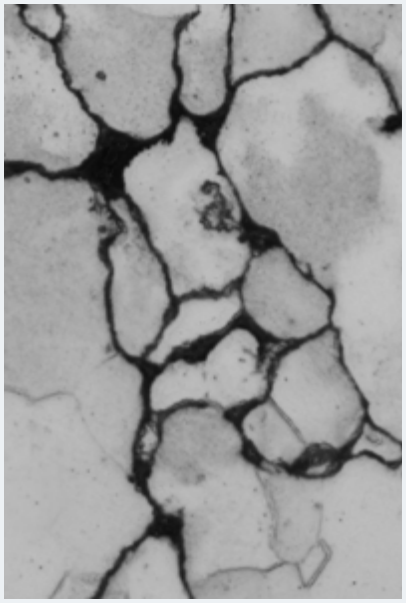
μ_r: Maximum permeability, an indication of how "quickly" the induction follows the magnetic field H.

B_s: Saturation induction, indicates how far the induction increases before the material is saturated and cannot be further magnetized.

SOFT MAGNETIC COMPOSITES (SMC)

The main constituent of soft magnetic composites is pure iron powder. The most notable feature of these soft magnetic particles is their electrically isolating coating which remains active even after pressing and curing.

Due to the coated iron powder particles the electrical resistivity of the material is high and the formation of eddy currents in alternating field applications is prevented.



This leads to a substantial reduction of eddy-current losses in electromagnetic applications as compared to traditional technologies.

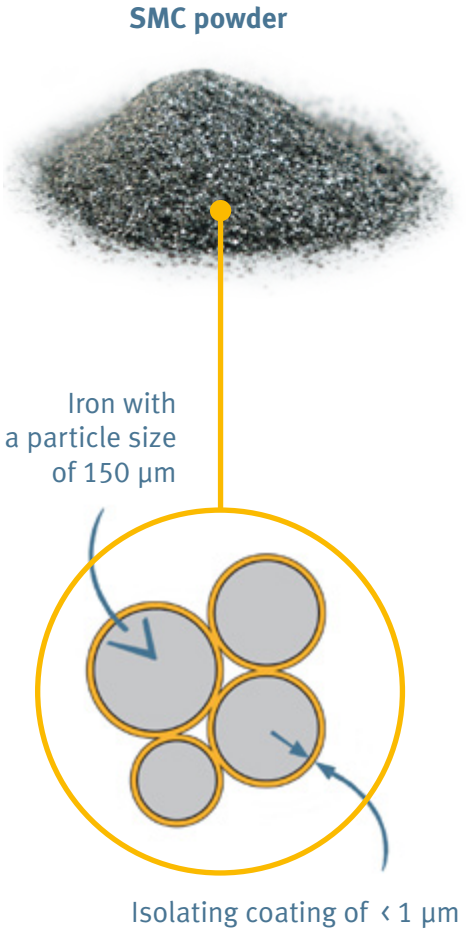
Another specific property of SMC is the extremely low remanence of this material.
The powder based structure and GKN's press technology enable the creation of 3-dimensional designs with these exceptional advantages.

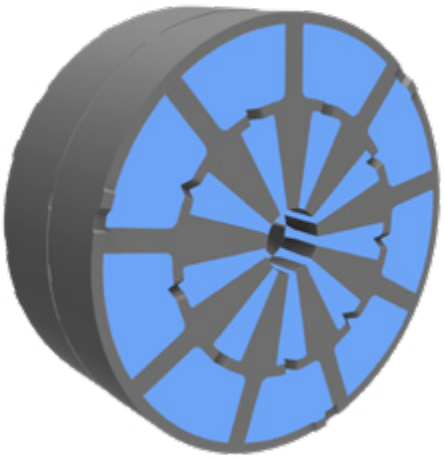
MANUFACTURING PROCESS FOR SMC COMPONENTS

The processing route for SMC components is characterized by an extremely lean sequence of manufacturing steps.

The powdered raw material is compacted into the desired shape on powder presses that have been specially developed for these products. This step allows to adjust the density, even within a component, depending on the requirements of the application.

Advanced materials and innovative production equipment enable GKN to realize densities up to 7.5 g/cm³. In the subsequent curing process that is carried out at relatively low temperatures below 600°C the SMC components attain their strength and are ready for assembling.





Optional:
overmould with coil

Optional:
coating

Compaction

Curing

Finished component

SMC

enables entirely new approaches in electric motor design, as demonstrated by GKN's spectacular transversal flux motor ELEKTRA.

CLAW POLE DESIGN

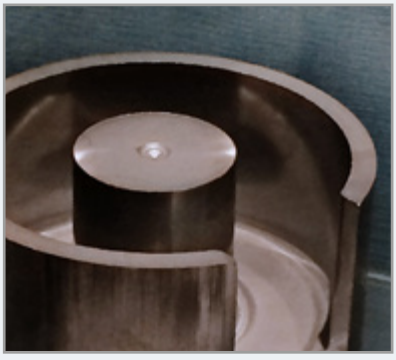
for transversal flux engines can only be realized with SMC.

GKN can support your developments in all stages from simulation and design up to testing of motors.

AXIAL FLUX MOTORS

made with SMC offer more design flexibility and allow to simplify assembling procedures.

GKN is your partner to design highly integrated systems based on powder metal products.

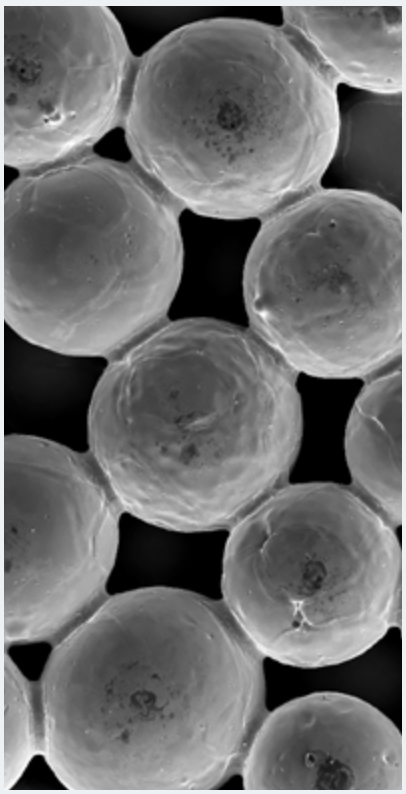


CORES

for inductors and transformers made from SMC offer clear benefits due to weight reduction and higher power density of the components.

SINTERED SOFT MAGNETIC MATERIALS

Sintered soft magnetic materials are superior to other materials in certain aspects.
Due to their complex near-net shape and high strength design they promise excellent magnetic properties and one hundred percent raw material utilization.



In addition to the density, which is variable as a free parameter affecting the saturation induction, for example, alloying additions such as phosphorus and silicon are available to adjust further magnetic properties depending on the application.

By alloying with up to 19% chromium it is also possible to produce ferritic structural parts that exhibit outstanding corrosion resistance.

MANUFACTURING PROCESS FOR SOFT MAGNETIC SINTERED COMPONENTS

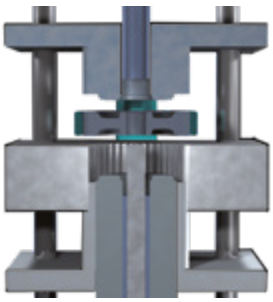
A variety of materials that can be adapted to the requirements and desired properties is available for the production of soft magnetic components.

Advanced compaction presses with multiple platen technology are used to produce highly complex parts with a homogeneous density distribution.

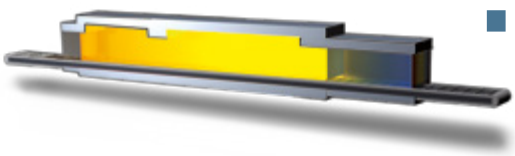
The “green” part produced by pressing attains its high strength and the desired magnetic properties in the subsequent high temperature sintering process in a controlled hydrogen atmosphere.

Finally, sintered structural parts can be finished without problems using secondary operations such as sizing, steam treatment, machining, or coating.

Metal powder

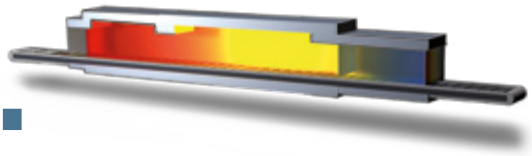


Optional:
sizing, machining, coating



Optional:
stream treatment, annealing

Compaction

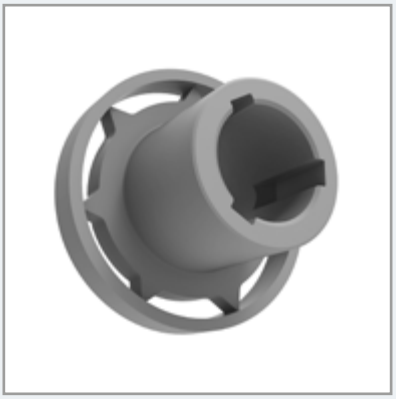


Sintering

Finished component

LINEAR ACTUATION

Soft magnetic components made by powder metallurgy technology have proven successfully by the millions in switching, lifting and proportional magnetic circuits thanks to their excellent performance.



ROTATIONAL ACTUATION

Due to the design freedom of sintering technology, components of complex shapes can be realized. They are custom-tailored to fit the magnetic and mechanical requirements of innovative, efficient applications.

MAGNETIC COILS

Sintered structural parts are ideal cores for compact, reliable magnetic coils due to their good magnetic properties and a high potential for integrated functions.

SENSOR SYSTEMS

High precision sintered parts are the core elements of many electromagnetic sensor systems and, due to their excellent reproducibility, guarantee continuously exact measurement data.

MATERIALS OVERVIEW

Sintered soft magnetic materials

Designation	Typical properties [1]										
GKN SM material code	Density [g/cm³]	Coercive force H_c [A/m]	Bmax @ 1200 A/m [T]	Permeability	Hardness	Hardness	UTS [MPa]	$YS_{0,2}$ [MPa]	A El [%]	E [GPa]	Composition
PM4EM 1000D	7.0	170	1.05	2,300	50 HRF	50 HB	195	115	12	140	Fe
PM4EM 1000E	7.25	165	1.20	2,900	55 HRF	55 HB	255	155	17	155	Fe
PM4EM 10P40D	7.15	150	1.25	3,200	55 HRB	95 HB	380	270	12	155	Fe0.45P
PM4EM 10P40E	7.4	130	1.35	3,600	65 HRB	115 HB	415	280	15	170	Fe0.45P
PM4EM 10S30D	7.2	85	1.30	5,000	75 HRB	135 HB	380	275	15	155	Fe3Si
PM4EM 50NiE	7.5	20	1.20	10,000	40 HRB	80 HB	275	170	15	110	Fe50Ni
PM4EM SS410C	6.7	390	1.15	340	85 HRB	165 HB	280	150	10	125	Fe12Cr
PM4EM SS410D	7.0	330	1.23	410	95 HRB	210 HB	320	190	14	140	Fe12Cr
PM4EM SS430C	6.7	320	1.06	320	70 HRB	120 HB	300	170	12	125	Fe16Cr
PM4EM SS430D	7.0	280	1.17	370	90 HRB	185 HB	340	200	16	140	Fe16Cr

[1] Fe [wt.-%] balance, Tested with standard rings under ideal processing; Values may vary for structural parts, [2] C; Co [wt.-%] < 0,1

Soft magnetic composites (SMC)

Designation	Typical properties [3]				
	B @ 10 kA/m [T]	µmax	Hc [A/m]	Iron losses at 1T	
				P @ 50Hz [W/kg]	P @ 400Hz [W/kg]
PM4EM 10	1.56	502	249	6	53
PM4EM 10 HS	1.55	550	272	6	69
PM4EM 11	1.56	472	249	6	53
PM4EM 11 HS	1.59	557	260	6	57
PM4EM 35	1.3	337	327	6	51
PM4EM 35 HS	1.26	332	392	8	72
PM4EM 110	1.55	454	210	5	45
PM4EM 110 HS	1.55	602	234	6	58

[3] C [wt.-%] < 0,1; Co [wt.-%] < 0,1, Tested with standard rings under ideal processing; Values may vary for structural parts

Chemical composition [2]						Standards			Application
Fe [wt-%]	P [wt-%]	Ni [wt-%]	Si [wt-%]	Cr [wt-%]	Other [wt-%]	DIN EN 10331	DIN 30910 Sint-	MPIF	
bal.	-	-	-	-	< 0.5	S-Fe 170	D 00	FF-0000-20W	Applications of low frequency current and permanently energized systems
bal.	-	-	-	-	< 0.5	S-Fe-165	E 00	FF-0000-20X	
bal.	0.45	-	-	-	< 0.5	S-FeP-150	D 35	FY-4500-17X	
bal.	0.45	-	-	-	< 0.5	S-FeP-130	E 35	FY-4500-17Y	
bal.	-	-	3	-	< 0.5	S-FeSi-80	n/a	FS-0300-12X	
bal.	-	50	-	-	< 0.5	S-FeNi-20	n/a	FN-5000-5Z	
bal.	-	-	-	13	< 1	n/a	C 43	SS-410L	Applications of low frequency current and permanently energized systems with high corrosion resistance
bal.	-	-	-	13	< 1	n/a	D 43	SS-410L	
bal.	-	-	-	18	< 1	n/a	C 42	SS-430L	
bal.	-	-	-	18	< 1	n/a	D 42	SS-430L	

UTS: ultimate tensile strength, **YS**: yield strength, **A/El:** elongation to fractur, **E**: Young's modulus

				Application
P @ 1000Hz [W/kg]	P @ 2000Hz [W/kg]	TRS [MPa]	Density [g/cm^3]	
139	304	39	up to 7.4	BLDC electric motors; Transversal flux machines; Transformers; High frequency soft magnetic application
229	513	121	up to 7.4	
155	352	42	up to 7.5	
168	411	136	up to 7.5	
134	296	62	up to 7.3	
201	498	149	up to 7.3	
128	298	44	up to 7.4	
152	344	112	up to 7.4	

CHECK LIST FOR ENQUIRIES ON SOFT MAGNETIC COMPONENTS

1. CUSTOMER INFORMATION

Company name _____

Company address _____

Business areas _____

Contact person _____

2. COMPONENT DETAILS

Component designation _____

Drawing/enquiry number _____

Target application _____

Annual quantities _____

Expected SOP & lifespan _____

Material (if specified) _____

3. APPLICATION DETAILS

Frequency	_____ ☐ DC _____ ☐ AC at frequency _____ Hz	
Max. Induction	_____ T ☐ (label)	☐ high priority
Applied field	_____ A/m	☐ high priority
Max. coercivity	_____ A/m	☐ high priority
Permeability	_____	☐ high priority
Max. losses	_____ W/kg at _____ Hz & _____ T	☐ high priority
Min. strength/ test method	_____ N/mm^2 in _____	

4. ADDITIONAL REQUIREMENTS

Rust protection

☐ oil impregnation ☐ steam treatment

☐ zinc plating ☐ others

Secondary operations

☐ welding/brazing ☐ machining

☐ bonding ☐ overmoulding ☐ others _____

5. DEVELOPMENT SUPPORT BY GKN

Blanks	☐ Yes	dimensions: _____	quantity: _____	date: _____
Sample parts (tool compacted)	☐ Yes	quantity: _____		date: _____
Others	☐ Yes	how: _____	quantity: _____	date: _____

6. COMMENTS

_____

_____

_____

MORE QUESTIONS?

Do you have any more questions? Or do you need more information about our innovative products, technologies or materials?

Then please contact us directly:

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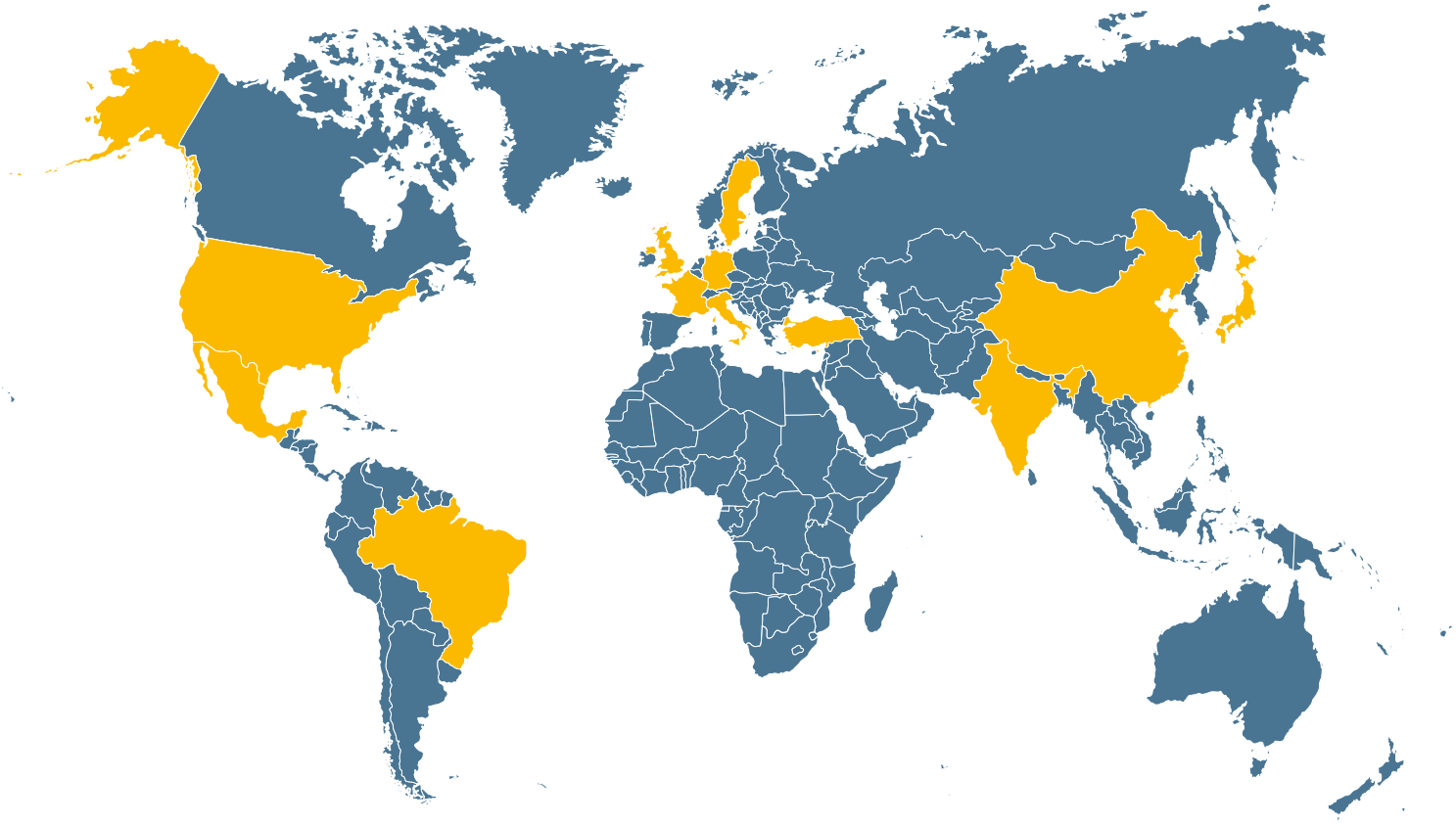

GKN Locations

Over 30 locations
in 12 countries
on 4 continents

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