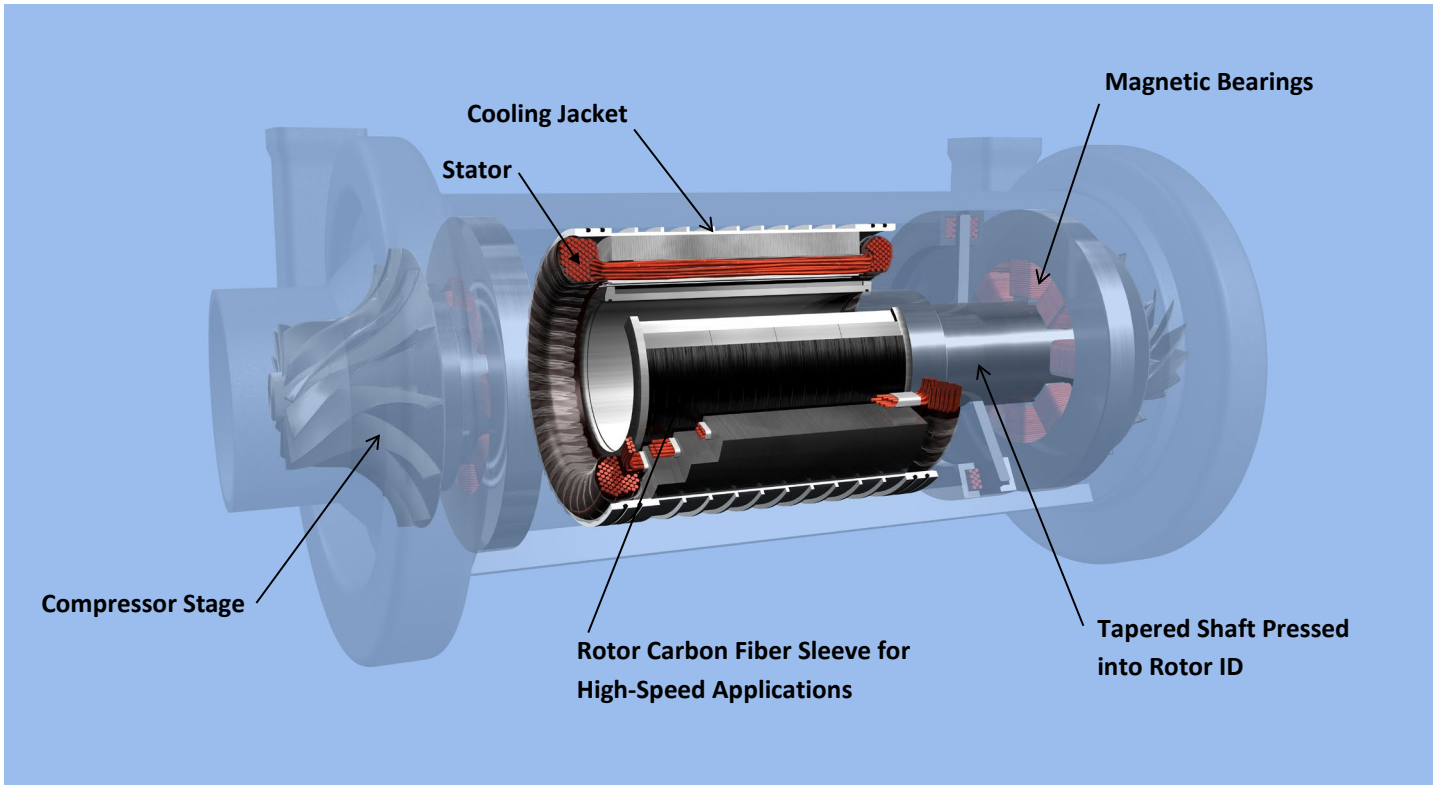
Permanent Magnet Motor/Generator Types from e+a



Two-Stage Compressor Diagram with e+a Rotor/Stator, Carbon Fiber Sleeve, Cooling Jacket, Tapered Shaft and Magnetic Bearings.

Permanent Magnet (PM) Motor/Generators

Many machine tool spindle manufacturers use induction motors for their low cost and ability to handle harsh environments, but on the whole, Turbomachinery applications like Heating, Ventilating & Air Conditioning (HVAC), Fuel Cell Compressors, Waste Water Blowers, and especially Power Generation and Energy Recovery systems like Micro-Turbines, ORC systems, and Automotive range extenders are primarily the domain of Permanent Magnet machines. This is due mainly to the PM Motor's high energy density, ability to operate at elevated tip speeds, high efficiency and allowance for large shaft diameters (providing for stiffer rotors and drive trains and better rotor-dynamics). Synchronous (PM) rotors can also achieve very high torques and have the dynamic properties to cope with this feature.

e+a Permanent Magnet Rotors with Carbon Fiber Reinforced Plastic (CFRP) Sleeves.

Contact Mike Drumm, 925 685-0227 mdrumm@eandaUSA.com www.eandaUSA.com Concord, CA https://motorscout.eunda.ch

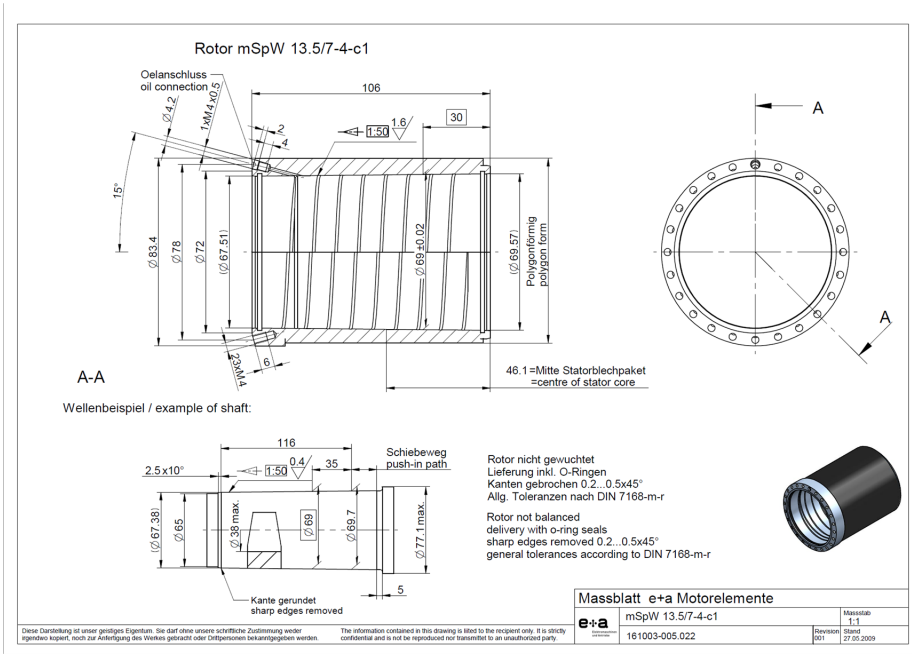
They are more temperature sensitive than induction motors but adequate cooling designs overcome this issue, and PM Motors fill application spaces just not suitable for asynchronous (Induction) machines.

PM Rotors with Tapered CFRP Sleeves

e+a Permanent Magnet rotors with Carbon-Fiber Reinforced Plastic (CFRP) sleeves have large rotor bores that allow very rigid drive trains (shaft and rotor). Since Permanent Magnets are temperature sensitive, e+a uses a simple, non-thermal mechanical procedure for shaft insertion into the rotor bore (tapered sleeve). With the tapered sleeve system, the rotor element is supplied with an internal 1:50 taper, and is attached to a customer-supplied shaft via a simple fitting procedure that involves a tapered shaft, sometimes an oil pump to expand the rotor and sleeve, and a hydraulic press to insert the shaft (see e+a manual on procedures for PM shaft insertion). This method not only secures the shaft tightly into the rotor bore but it also provides a pre-load onto the CFRP sleeve that insures the magnets will be stable & immobile over the entire speed range of the rotor. e+a uses a special composite consisting of resin and carbon fibers developed specifically for high temperature strain loads. The maximum permissible temperature can be adjusted on request to meet customer specifications. e+a developed its own procedure for manufacturing CFRP sleeves to allow flexibility in its construction for custom applications. As a result, rotor elements with exceptionally high power densities and circumferential speeds can be built efficiently and cost effectively; in addition, materials used for the CFRP sleeve have a negative temperature coefficient, so as the rotor heats up during normal operation the contraction of the sleeve provides an additional level of safety and rotor integrity.

Advantages of Synchronous Motor Elements

Synchronous motor elements with permanent magnet rotors can achieve extremely high torques and very high tip speeds (>350 m/sec). These products are characterized by large rotor bores, high power densities and extremely short starting times. The rotors can be installed quickly without having to thermally treat the rotor or shaft beforehand, and shafts installed in PM motors can be removed and the rotor can be reused. e+a synchronous motor elements can be operated with standard converter systems that are suitable for use with PM motors. e+a offers support during the prototyping phase and advice on the design of the overall drive system to help achieve satisfactory operating characteristics and shorten time-to-market.



Typical Drawing of e+a Rotor with CFRP Sleeve Provided to Customers for use in System Integration.

Direct Assembly - Permanent Magnet & CFRP Sleeve

With the direct assembly method, magnets and the CFRP sleeve are fit directly to the customer-supplied shaft. This option is primarily for volume OEMs and allows for a larger shaft diameter compared to the tapered sleeve system. Apart from that, the same technical boundary conditions apply to both permanent magnet rotor systems relative to power density, circumferential speed and ambient temperature.

Directly Assembled e+a PM Rotor

Permanent Magnet Rotor with Steel Sleeve

Depending on the environmental conditions motors are exposed to, sleeves made from special ferrous alloys can be used to increase the durability of rotors operating under higher temperatures, meet special criteria regarding surface properties, provide better rotor cooling while limiting shaft temperatures, or accommodate cryogenic applications where the rotor and stator are immersed in LNG, LN, LH or other cryogenic liquid.

The Ferrous Alloy Sleeve design can also be operated over a much broader temperature range than the CFRP sleeve.

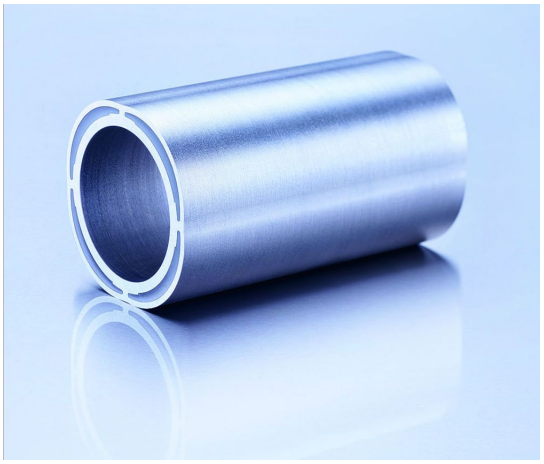
PM Rotor with a Ferrous Alloy Sleeve

Synchronous Rotors with Interior PM Magnets- IPM

With the development of the new Internal Permanent Magnet (IPM) motor series e+a has directly targeted the needs of machine tool spindle manufacturers requiring high torque in the basic speed regime combined with a wide field weakening range.

The IPM design produces very low heat loss inside the rotor, significantly lowering shaft heating compared with conventional rotor designs. In many cases a serial inductor between the controller/inverter and the motor is not required. Further advantages of this series include large rotor bores as well as maximum speeds up to 140m/s.

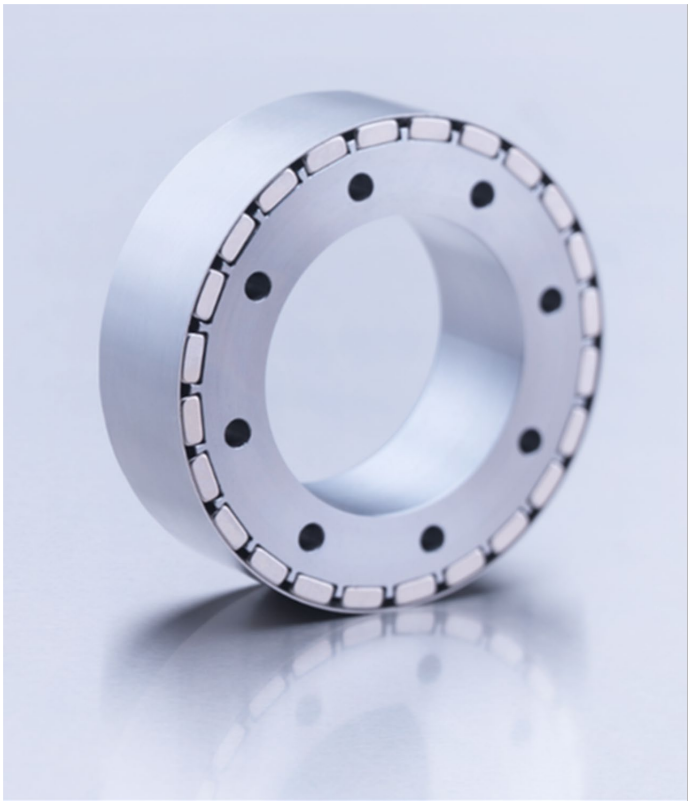
e+a delivers IPM rotors ready for installation and recommends that rotors be mounted on the shaft via a thermal joining process. Necessary mounting specifics are provided by e+a.



Synchronous Rotor with Interior PM Magnets - IPM

Advantages of e+a IPM Motors

- High torque in the basic speed regime (up to 40% higher than Asynchronous Motors/ASM)
- Wide constant power range (leads to smaller and simpler controllers).
- Low rotor temperature typically without the need of a serial inductor (lower system cost & weight)
- Maximum speed up to 140m/s (corresponds to the maximum speed of many CuSt ASM rotors)
- Large rotor bore compared to ASM rotors
- Robust construction



Torque Motor with Metallic Sleeve

Torque Motor with Metallic Sleeve

e+a torque motors come with a metallic sleeve to improve their durability and reliability. This ensures that even under unfavorable conditions, the magnets are protected from mechanical damage and remain solidly attached to the rotor element.

Core Magnet with Metallic Sleeve

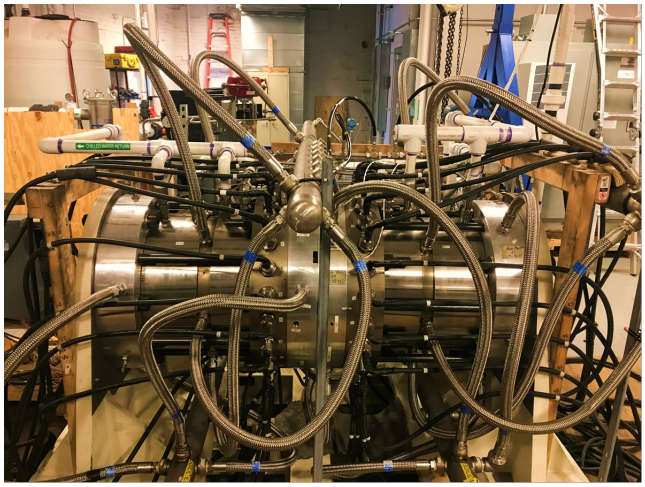
The core magnet design can be used in 2-pole, high speed applications such as Fuel Cell Compressors by achieving significant electrical and mechanical performance in a synchronous motor with a small footprint, despite the low number of poles. The shaft ends, sleeve and core magnet are combined into a single assembly during manufacture using a straightforward process, and the metallic sleeve protects the magnet from external impacts, provides for rotor/shaft integrity and aids in rotor cooling.

Core Magnet Rotor with Metallic Sleeve

Applications for PM Motors & Generators Power, Speed and Primary Use

Power Generation

Power(KW)	Speed (RPM)	Primary Use
1.3	500,000	Man Portable Gen
8	180,000	GTE, Airborne
80	95,000	Truck Range Extender
100	40,000	ORC
140	64,000	GTE Gen, Foil Brgs.
160	51,000	GTE Gen, Foil Brgs.
350	75,000	Truck Range Extender
490	36,000	GTE Gen, Foil Brgs.
1200	31,000	Power Generator
1600	25,000	Power Generator



1.6MW, 25,000 RPM System for Shipboard Power Generation. Shown are two Generators configured Back-to-Back for Testing.

160KW, 51,000 RPM Generator for Gas Turbine Engine, Foil Bearings & Flexible Coupling

Housing for Land-Based Gas Turbine Engine Power Generation System, including GTE, Generator & Inverter. Replaced System with Gearbox, Oil-Supply, Large 50/60Hz Generator and Controller.

Waste-Water Treatment

Power(KW)	Speed (RPM)	Primary Use
36	50,000	Waste-Water Blower
55	30,000	Waste-Water Blower
75	30,000	Waste-Water Blower
110	25,000	Waste-Water Blower
160	25,000	Waste-Water Blower
220	21,000	Waste-Water Blower

Heating, Ventilation & Air Conditioning (HVAC)

Power(KW)	Speed (RPM)	Primary Use
300	24,000	HVAC Compressor
400	24,000	HVAC Compressor

Automotive

Power(KW)	Speed (RPM)	Primary Use
12	120,000	Fuel Cell Compressor
15	95,000	Fuel Cell, Solid Core Magnet
43	5,000	Traction Motor
80	95,000	Truck Range Extender
100	21,000	Traction Motor
200	25,000	Traction Motor

Concrete Cutting: 16KW, 9,000 RPM

Cryogenic Pump Applications: Land & Sea-Based

Cryo, LNG Pumps

Power(KW)	Speed (RPM)	Primary Use
2.2	350	Hi-Torque, 30 Pole
16	8,000	LNG Pump
100	8,000	LNG Pump
250	7,000	LNG Pump

Machine Tool: Honing, Milling, Grinding, PCB

Power(KW)	Speed (RPM)	Primary Use
0.76	250	29Nm Machine Tool
2	250,000	Turning Center
100	40,000	Honing Machine
100	10,000	1,000Nm, Milling Mach.
120	230	5,000Nm, PCB Drilling
120	30,000	Grinding Machine
140	24,000	Tapping Machine