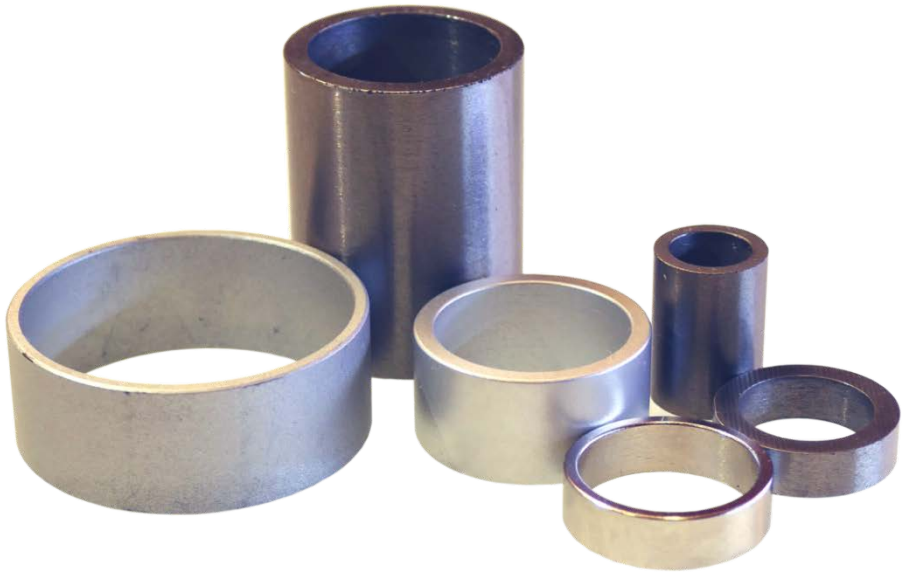
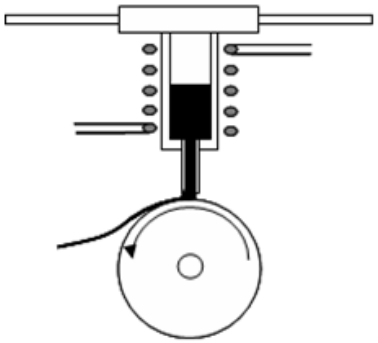
Hot Pressed NdFeB Rings



Hot Pressed magnets are radially oriented NdFeB rings who's orientation is obtained by mechanical pressing of the Rare Earth powers through a process called Backward Extrusion

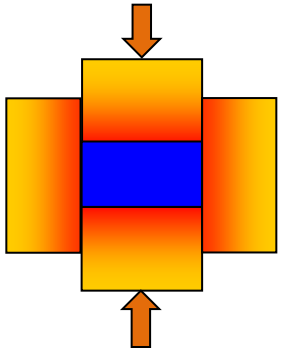
Hot Press Manufacturing Process

Rapid Melt Spin → **Cold Press**

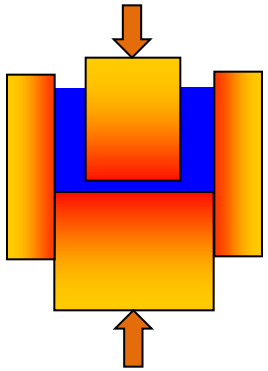


↓

Hot Press → **Hot backward extrusion**

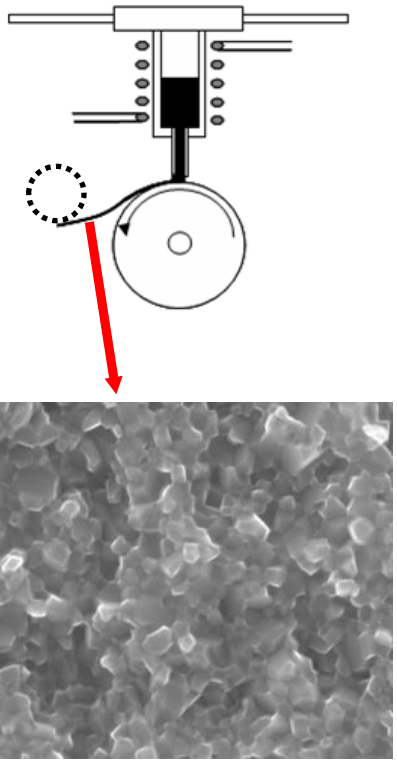


600~850 C
Isotropic Magnets
D=7.5-7.6g/cm3

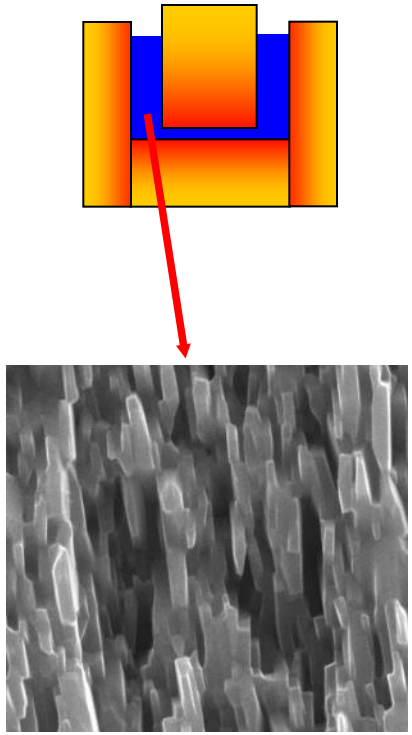


710~920 C
Anisotropic Magnets
D=7.5-7.6g/cm3

Microstructure Alignment



40nm

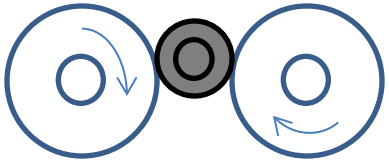


200nm

Radially aligned grains are formed by anisotropic growth and grain rotation during the hot extrusion pressing process

Cutting and Grinding

OD Grinding → Cutting Ends → ID Grinding →



Finish OD Grinding → Appearance and Crack Inspection → Ultrasonic Cleaning →

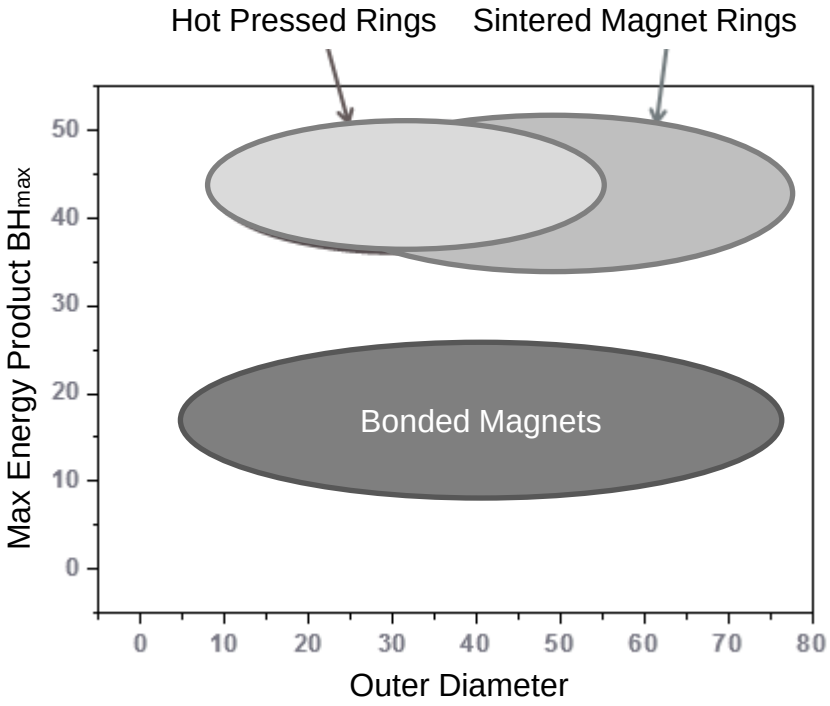
Coating or Plating → Inspection → Shipping

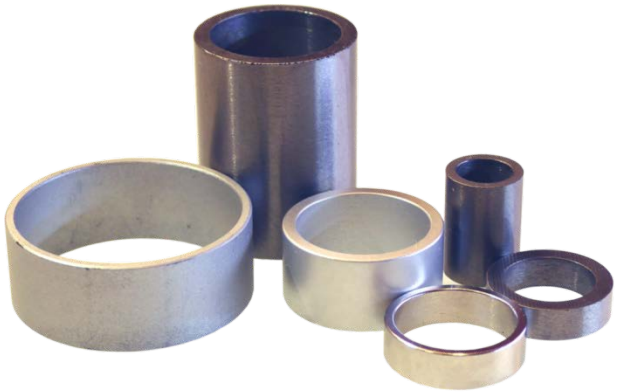
Dimensions and Tolerances

Dimensions (mm)	min	max
Inner diameter/Outer diameter	0.7	0.9
Height	0.5	50
Diameter	10	50
Optimum Diameter	20	40

Tolerances(mm）	OD	ID	H	concentricity	roundness
Machined magnets	±0.03	±0.03	±0.1	0.03	0.03
Coated magnets	±0.04	±0.04	±0.05	0.05	0.03

Properties of Ring Magnets

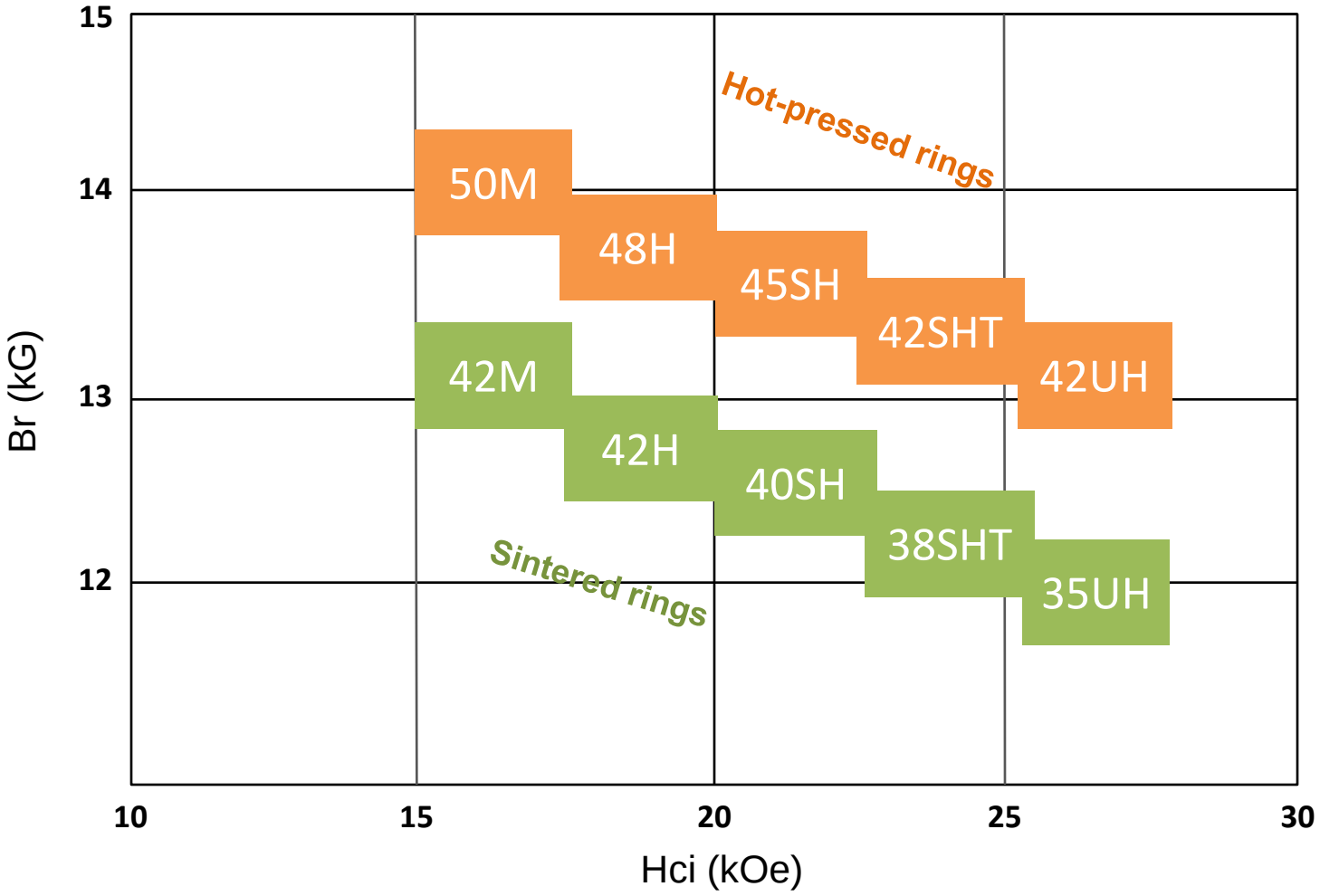




Various sizes of HP rings

Hot Press techniques can be used to produce high-performance rings with small diameters

Magnetic Properties of Ring Magnets



Physical Properties of Ring Magnets

Hot Pressed						
	Value	#1	#2	#3	#4	#5
Before HAST	Visual Inspection	OK	OK	OK	OK	OK
	OD (mm)	26.65	626.66	26.66	26.66	26.65
	ID (mm)	22.03	22.04	22.05	22.04	22.03
	Thickness (mm)	12.16	12.18	12.18	12.06	12.14
	Volume (cm^3)	2.15	2.15	2.15	2.13	2.14
	Surface (cm^2)	22.13	22.17	22.17	21.99	22.1
	Mass (g)	16.314	16.193	16.254	16.241	16.361
	Density (g/cm^3)	7.6	7.52	7.57	7.62	7.63
After HAST	Visual Inspection	OK	OK	OK	OK	OK
	Mass (g)	16.307	16.19	16.252	16.238	16.358
	Weight Loss (%)	0.04	0.02	0.01	0.02	0.01
	Weight Loss (mg/cm^2)	0.29	0.14	0.09	0.15	0.1

Sintered						
	Value	#1	#2	#3	#4	#5
Before HAST	Visual Inspection	OK	OK	OK	OK	OK
	OD (mm)	26.65	26.64	26.64	26.65	26.65
	ID (mm)	22.02	22.01	22.02	22.03	22.02
	Thickness (mm)	12.05	12.09	12.09	12.09	12.1
	-	-	-	-	-	-
	Surface (cm^2)	21.964	22.016	22.013	22.022	22.041
	Mass (g)	15.837	15.832	16.127	16.073	16.099
	Density (g/cm^3)	7.43	7.4	7.55	7.53	7.52
After HAST	Visual Inspection	OK	OK	OK	OK	OK
	Mass (g)	14.39	15.534	14.41	16.065	16.055
	Weight Loss (%)	9.14	1.88	10.65	0.05	0.27
	Weight Loss (mg/cm^2)	65.893	13.499	77.998	0.3663	1.9782

Hot Press parts have superior corrosion resistance to sintered magnets

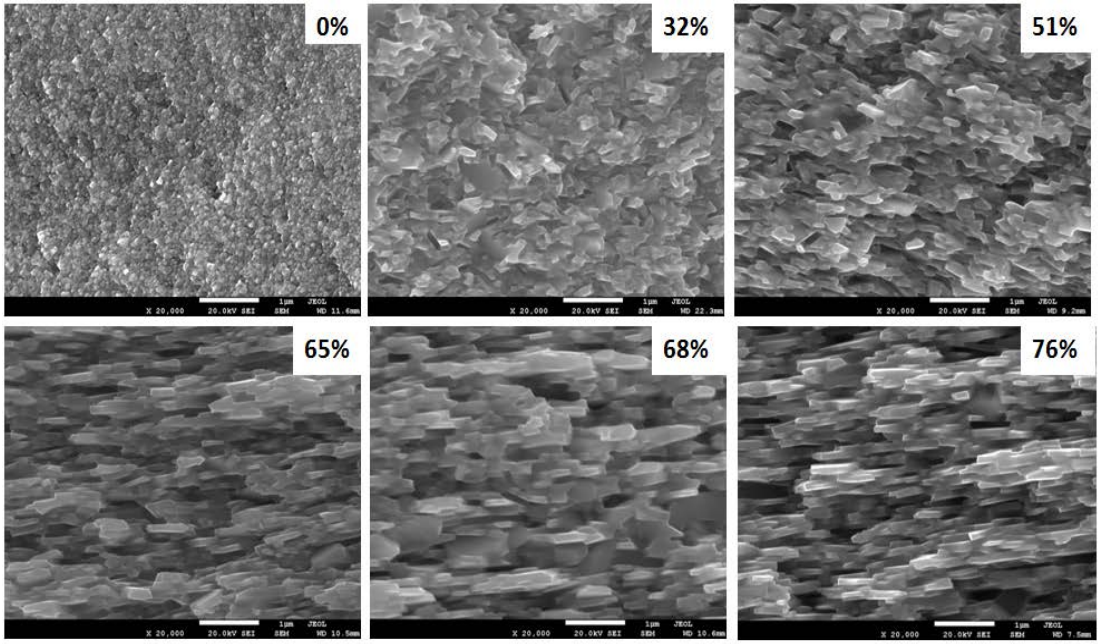
Comparison of Radially Oriented Sintered to Hot Pressed Magnets

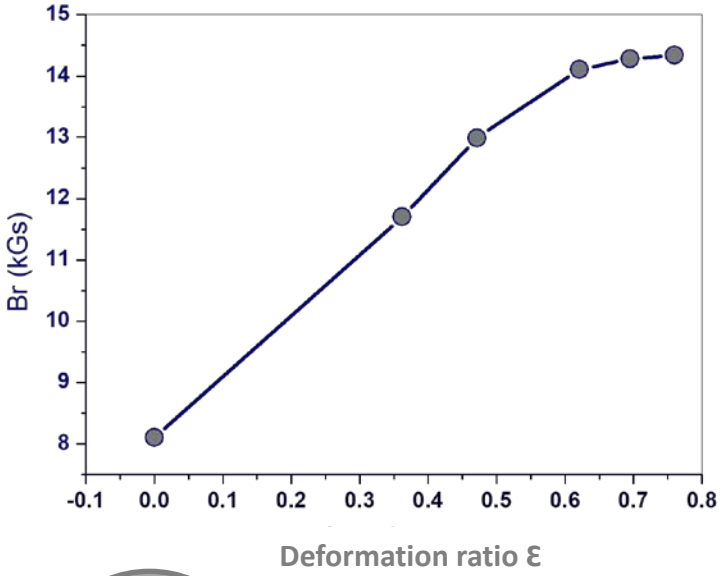
Item	Sintered ring	Hot-pressed ring
Surface magnetic flux waveform	Rectangular wave	Rectangular wave
Number of poles	Variable by magnetization	Variable by magnetization
Magnetized position	Variable by magnetization	Variable by magnetization
Skew magnetization	Yes	Yes
Recommended inside-to outside diameter ratio	~0.8	~0.8
Recommended length (mm)	1~50	1~50
Grades	N45，45H，42SH，35UH	N48，48H，45SH，38UH
Recommended OD (mm)	D20~D70	D8~D50
Corrosion resistance	poor	good

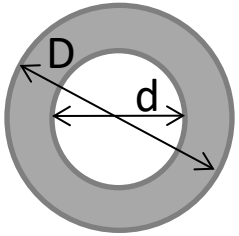
Hot Pressed Magnetic Properties

Grade	Br		Hcb		Hcj		(BH)max	
	T	(kGs)	(kA/m)	(kOe)	(kA/m)	(kOe)	kJ/cm^3	MGOe
50M	1.4~1.45	14~14.5	≥1043	≥13.1	≥1114	≥14	374~406	47~51
45M	1.33~1.37	13.3~13.7	954~1058	12.0~13.1	≥1273	≥16	318~366	40~46
42M	1.29~1.32	12.9~13.2	939~1034	11.8~13.0	≥1273	≥16	302~342	38~43
48H	1.35~1.4	13.5~14.0	1042~1114	13.1~13.6	≥1432	≥18	342~366	43~46
45H	1.32~1.35	13.2~1.35	954~1042	12.5~13.1	≥1432	≥18	318~342	40~43
42H	1.29~1.32	12.9~13.2	931~1010	12.2~13.1	≥1432	≥18	286~326	36~41
40H	1.26~1.29	12.6~12.9	931~1010	11.7~12.7	≥1432	≥18	286~318	36~40
45SH	13.2~1.35	12.9~13.3	954~1042	12.5~13.1	≥1592	≥20	318~342	41~44
42SH	1.29~1.32	12.9~13.2	962~1042	12.2~13.1	≥1592	≥20	302~326	38~41
40SH	1.26~1.29	12.6~12.9	939~1010	11.8~12.7	≥1592	≥20	286~318	36~40
38SH	1.22~1.26	12.2~12.6	923~986	11.6~12.4	≥1592	≥20	278~310	35~39
35SH	1.18~1.23	11.8~12.3	891~962	11.2~12.1	≥1592	≥20	246~286	31~36
38UH	1.22~1.26	12.2~12.6	907~986	11.4~12.4	≥1989	≥25	278~318	35~40
35UH	1.18~1.23	11.8~12.3	891~962	11.2~12.1	≥1989	≥25	246~286	31~36

Orientation Properties







$\varepsilon = (d*d) / (D*D)$

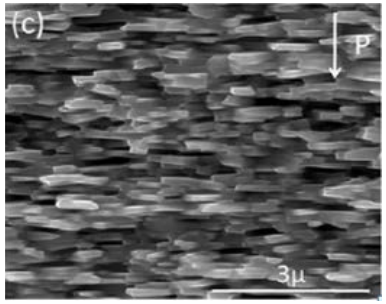
Higher deformation ratio leads to a higher alignment degree.
The deformation ratio can determine the remanence of hot-deformed ring.

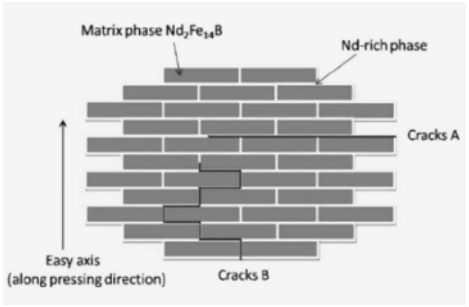
Temperature & Physical Properties

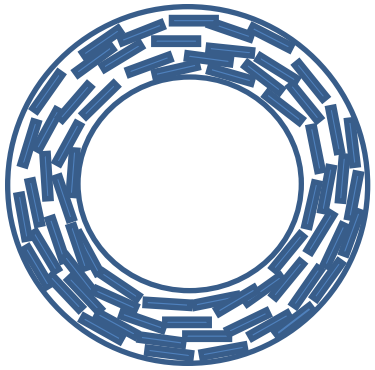
	Unit	Data
Temp. Coefficient of Br α	%/℃	-0.10
Temp. Coefficient of Hci	%/℃	-0.50
Recoil Permeability		1.05
Magnetizing Force	T	2.5
Density		7.6~7.7
Curie Temperature	℃	360
Specific Heat	J/Kg℃	550
Thermal Conductivity	W/m℃	4.80
Thermal Expansion Coefficient (20～200℃)	×10-6/℃	radially 1～2
		axial -1～0
Electrical Resistivity	×10-8Ωm	135
Ring Crushing Strength	MPa	150
Young's Modulus	MPa	152000
Vickers Hardness	---	750

Comparison of Mechanical Properties

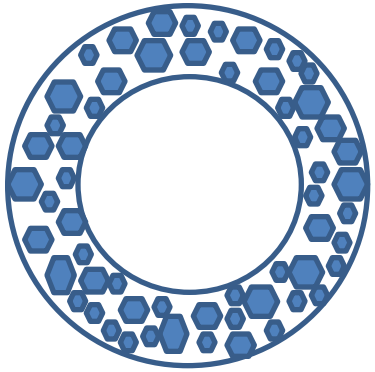
	Fracture toughness （MPa·m-1/2）	Bending strength （MPa）
Sintered ring	4~5	150~200
hot-pressed ring	6~7	~400







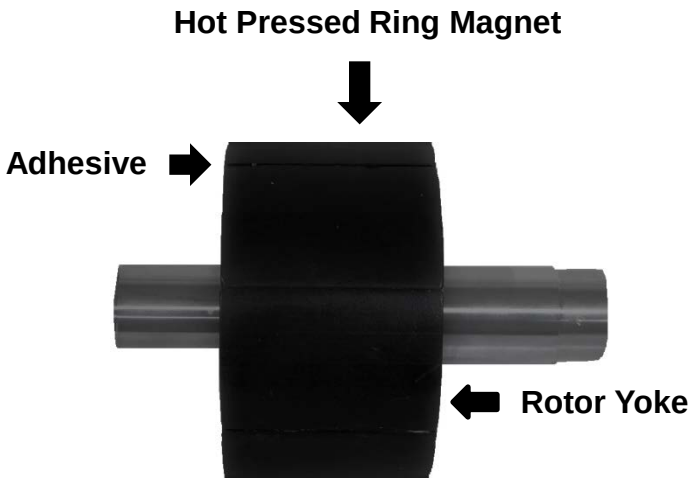
Grains in hot-deformed ring



Grains in sintered ring

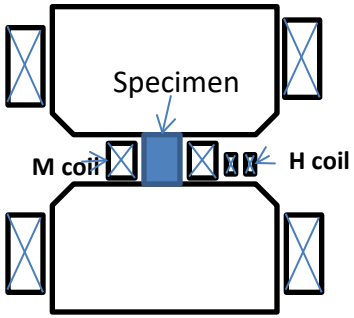
Thermal Expansion Coefficient
(20～200℃)

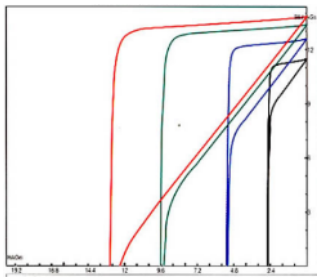
Rotor Yoke	**$12x10^{-6}$**
Adhesive	**$50~100x^{-6}$**
Radial Ring	**$1~2x10^{-6}$**

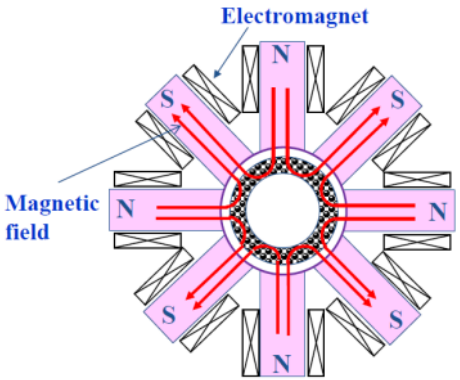


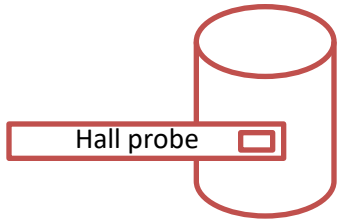
Magnetic Properties Testing

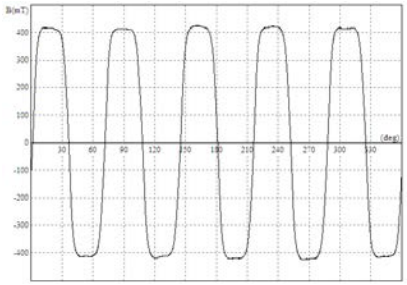
B-H Curve 1 piece/lot	Magnetic Flux 2~20 pieces/lot	Surface Flux Density 2~20 pieces/lot
1. A few rectangular specimens are cut from a ring magnet. 2. Fully magnetized by pulse field. 3. Measure by B-H tracer.	1. Machined ring magnets are magnetized in a multi-pole magnetizing fixture. 2. Measured flux in the fixture by a flux meter.	1. Machined ring magnets are magnetized in a multi-pole magnetizing fixture. 2. Measured by gauss meter.







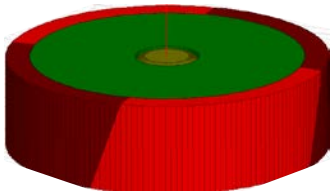


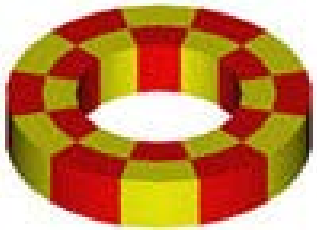


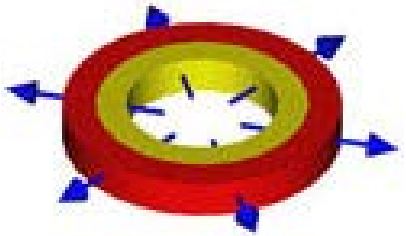
Plating & Coatings

- Epoxy (Spray or Dip Process)
- Ni，Ni-Cu-Ni，NiCuNi+Cr
- Zinc
- Passivation
- Everlube
- Teflon
- Aluminum (Vapor Deposition Process)

Magnetization of Ring Magnets





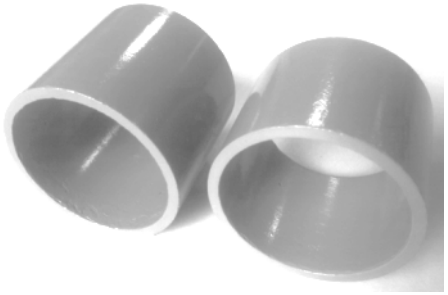


Type	Skewed Multipole	Multipole	Unipolar
Applications	Servo motors Electric Steering Low-cogging motors Magnetic geared motors	Servo motors Generators Compressors	Linear actuators Compressors Magnetic bearings

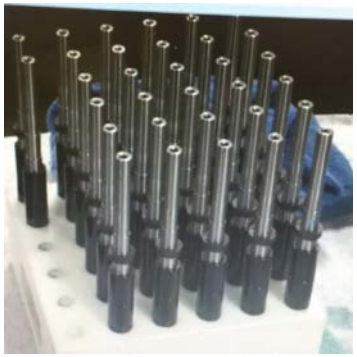
Servo Motor Applications

- Ultra low cogging torque and accurate positioning
- Wide operating range with a high overload capacity for stability control
- Excellent temperature characteristics for safety and reliability
- Quick responsiveness with maximum 6000 rpm in approximately 5 milliseconds

Automotive Motor Applications



EPS

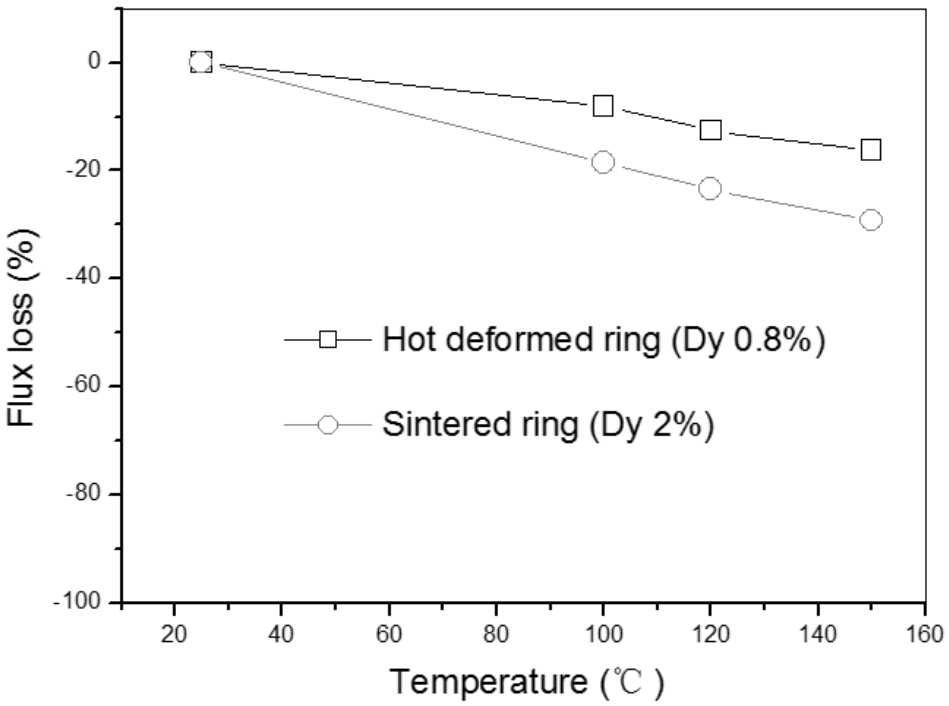


Seat Motors

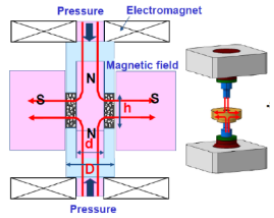
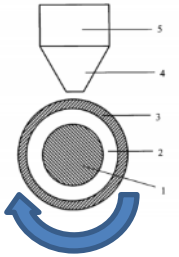
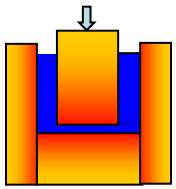
Exhaust Valves

- Electric Power Steering
- EGR Valves
- Seat Motors
- Pumps

Less Heavy Rare Earth Content



Overall Comparisons

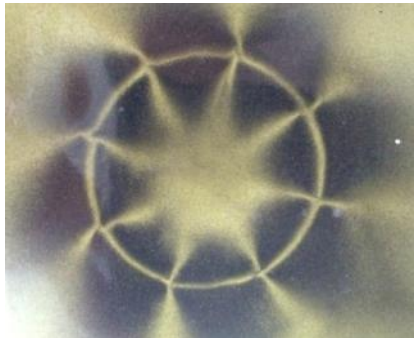
	Pressing	Magnetic properties	Magnetic angle deviation	Corrosion resistance
sintered ring	 magnetic repulsive	poor	0°	poor
	 Rotation	good	poor (15~25°)	poor
hot-pressed ring		better	0°	good

Magnetic Angle Deviation

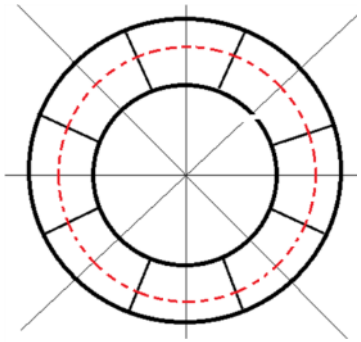
Size	Pressing Method	1	2	3	4	average
D39.35*D32.5*27	Hot-pressed	0.52°	0.38°			0.45°
D39*D30*25.5	Rotation sintered	14.55°	13.92°	12.55°	14.66°	13.92°
D14*D10*20	Rotation sintered	22.44°	24.68°	22.89°	22.96°	23.24°
D30*D24*20	Rotation sintered	18.39°	18.41°	15.87°	14.36°	16.75°

Rotation pressed ring have magnetic angle deviation 10° ~20°
Hot-pressed ring have magnetic angle smaller than 1°

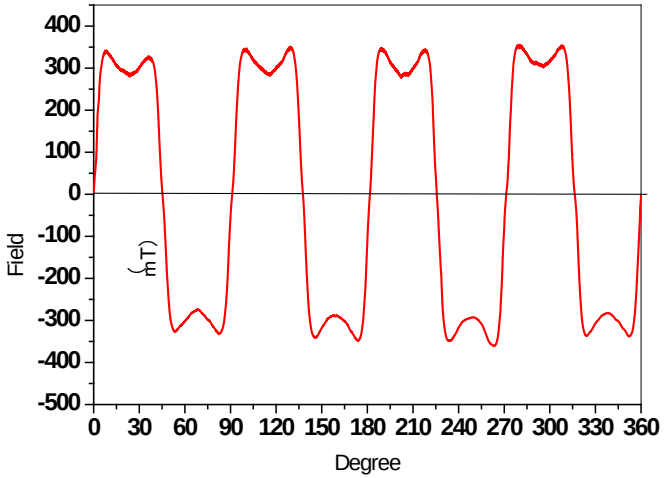
Radial vs Rotational Alignment



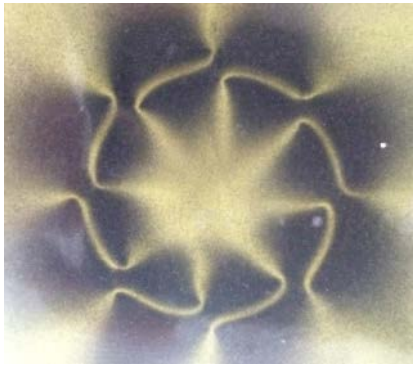
Radial
（hot-pressed ring）



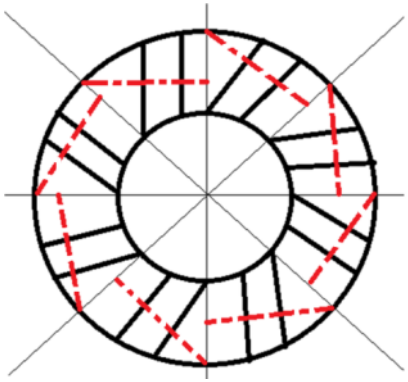
Alignment



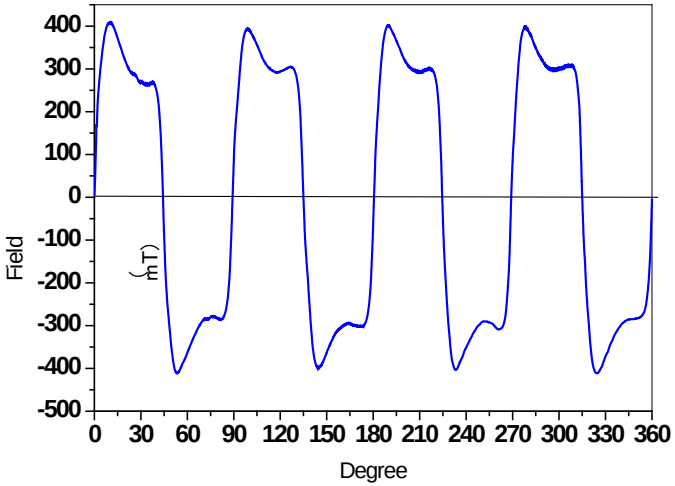
Wave Form



Rotating
（sintered ring）

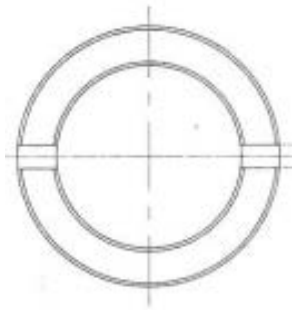


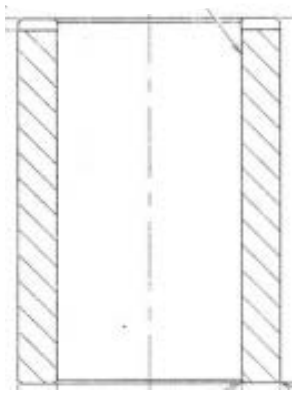
Alignment

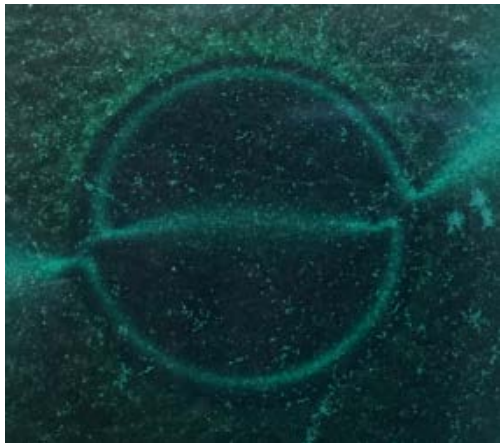


Wave Form

Defect of rotation pressing of sintered ring







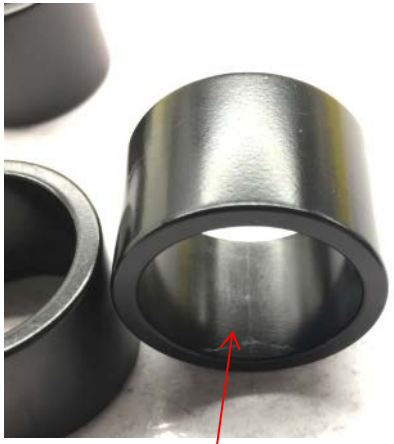
N/S boundary deviation（~7°）

For high precision valve motors, rotational pressing of sintered NdFeB rings is not recommended

Cracking issues with sintered rings

Crack during pressing

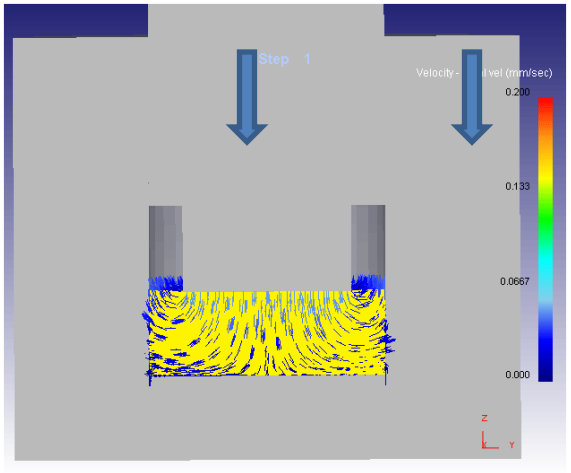
Crack after sintering

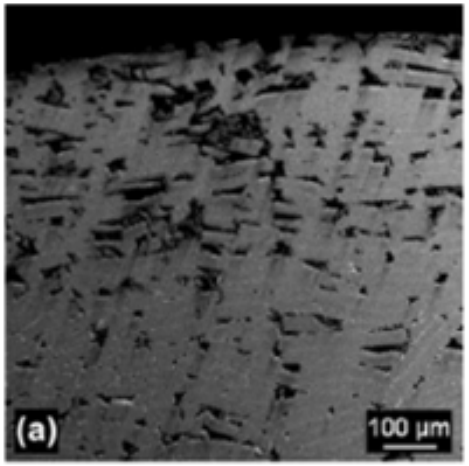


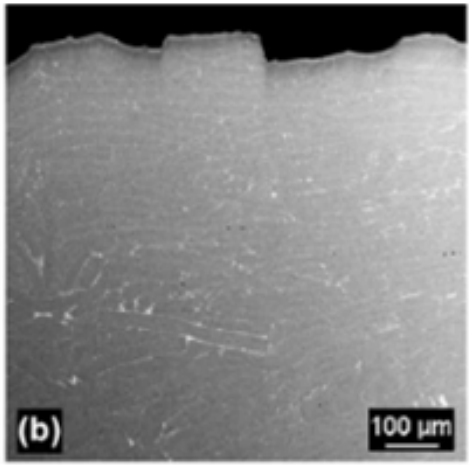
Crack after coating

Internal stress will lead to cracking of sintered rings

Better Mechanical Strength

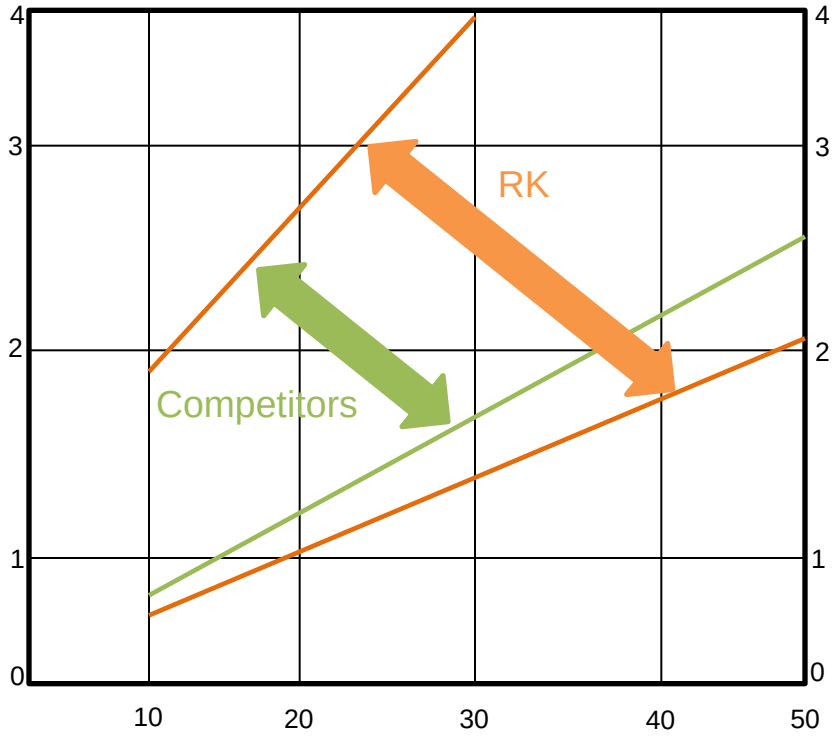






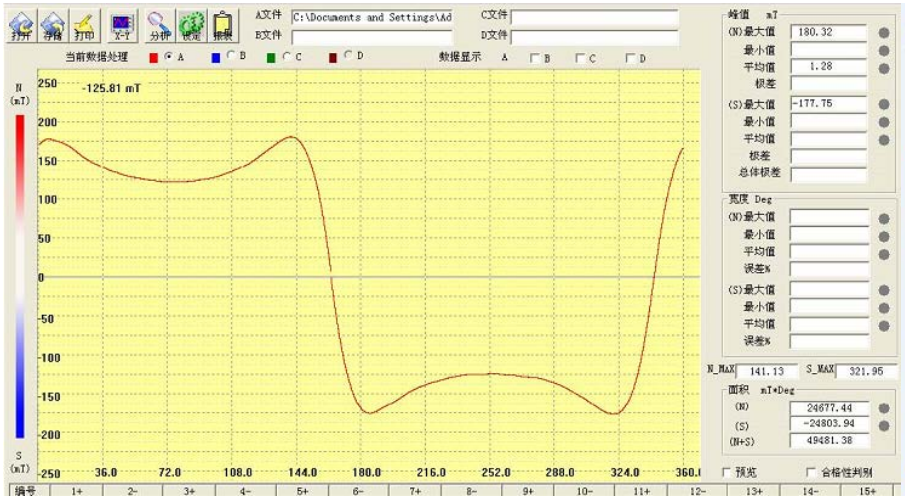
Supply of additional back pressure on the free surface helps to achieve a crack-free and mechanically stronger ring magnet

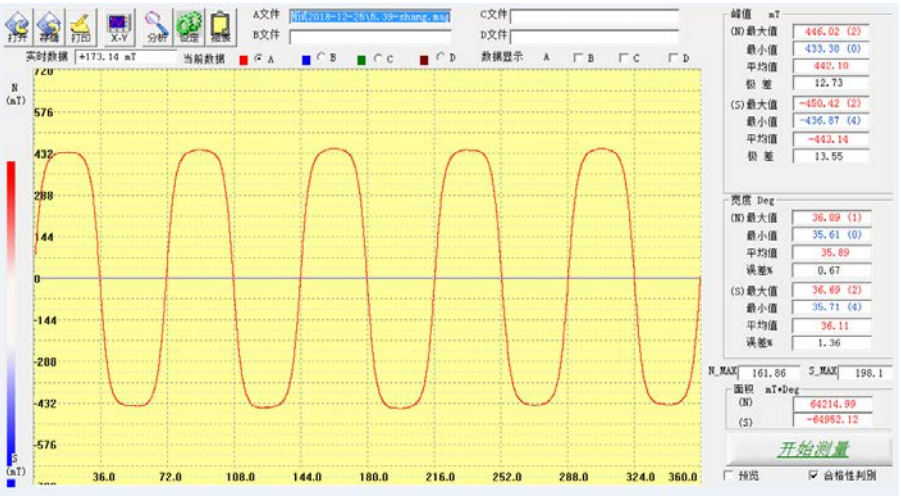
Thin-wall thickness



Ability to produce hot-pressed ring magnets (d/D >0.9) with a smaller wall thickness than other suppliers

4 Pole and 10 Pole Magnetization





Typical Packing

Hot Pressed NdFeB rings have strong magnetic attraction in the radial field and must be packaged with certain minimum distances from each other in a non collapsible packing material