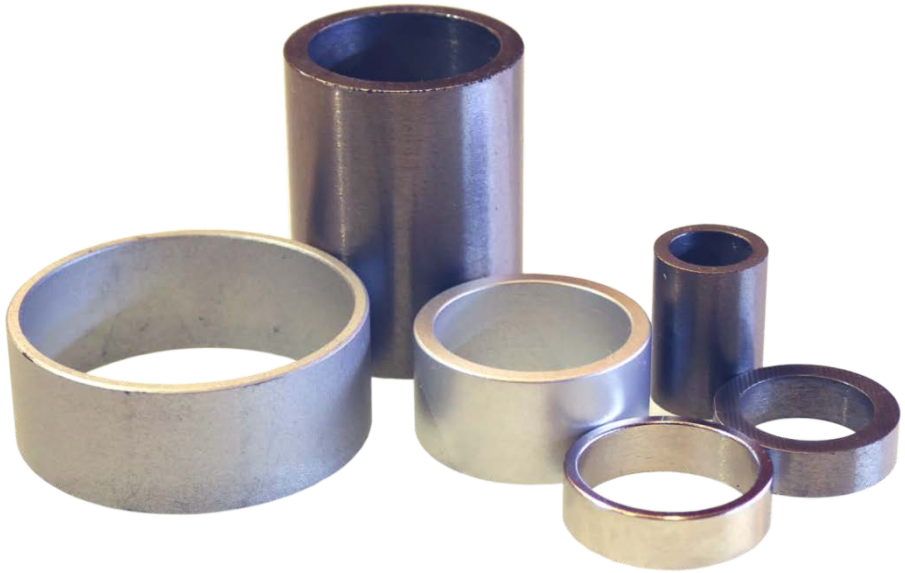
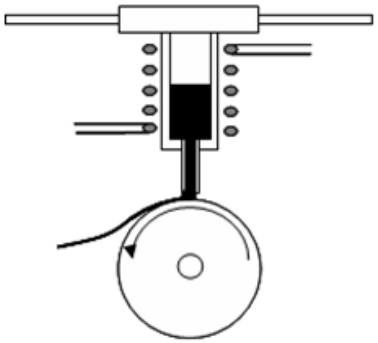
Hot Pressed NdFeB Rings



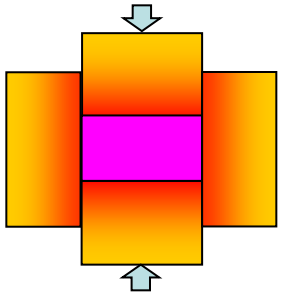
Hot Pressed magnets are radially oriented NdFeB rings who's orientation is obtained by mechanical pressing of the Rare Earth powers through a process called Backward Extrusion

Hot Press Manufacturing Process

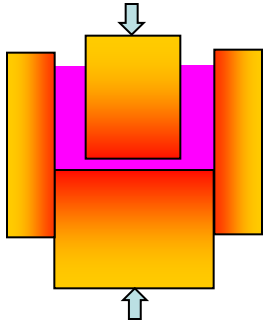
Melt Spinning → **Cold Pressing**



Hot Pressing → **Hot backward extrusion**

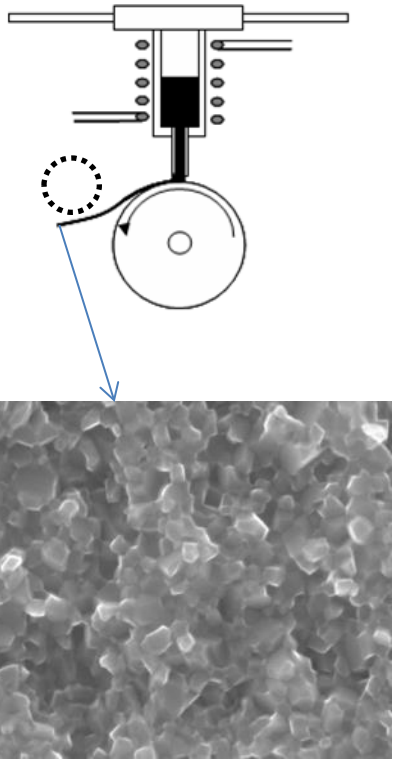


600~800 C
Isotropic Magnets
D=7.6g/cm3

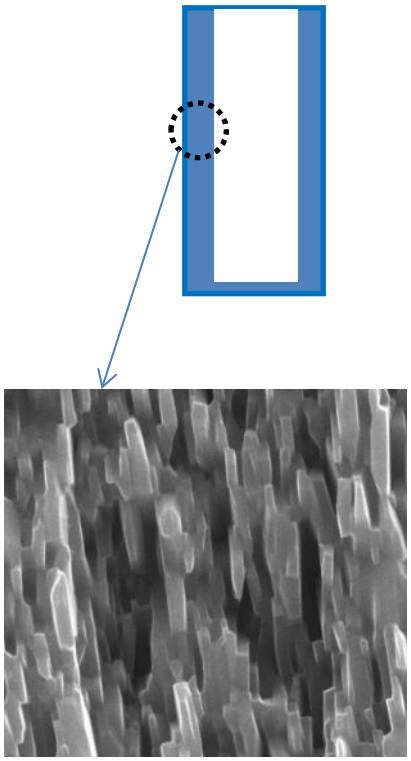


700~900 C
Anisotropic Magnets
D=7.6g/cm3

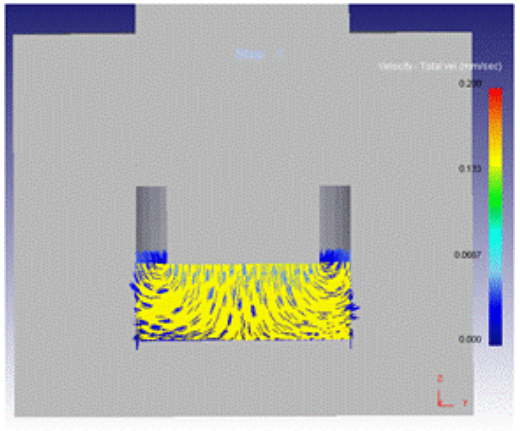
Microstructure Alignment



40nm



200nm

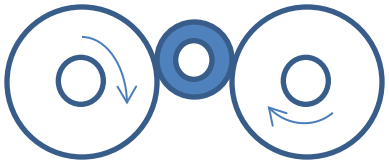


Backward extrusion process

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

Cutting and Grinding

OD Grinding → Cutting → ID Grinding →



→ OD Grinding **(finish)** → Appearance and Crack Inspection → Cleaning →

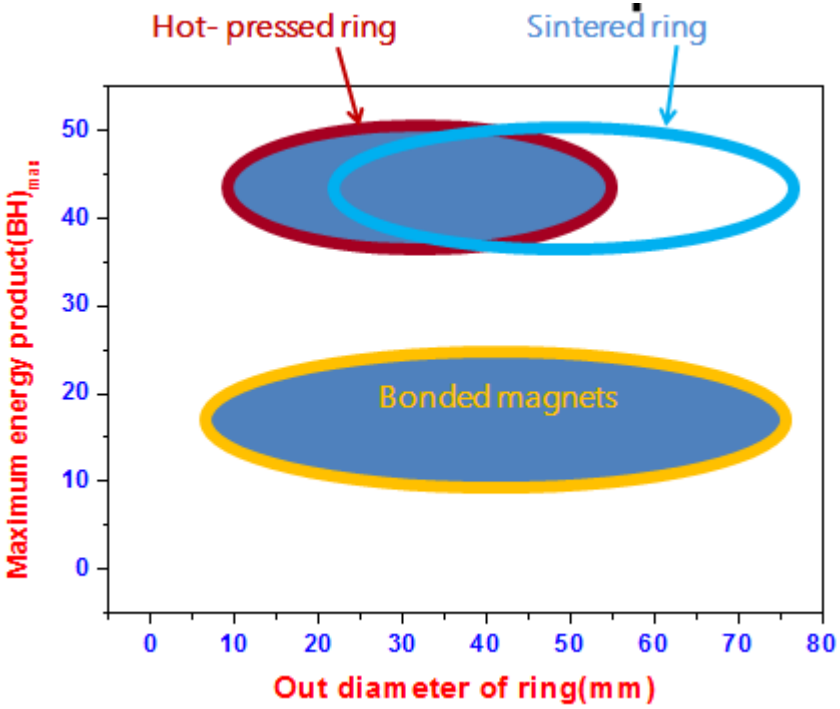
→ Coating → Inspection → Shipping

Dimensions and Tolerances

Dimensions (mm)	min	max
Inner diameter/Outer diameter (ID/OD)	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

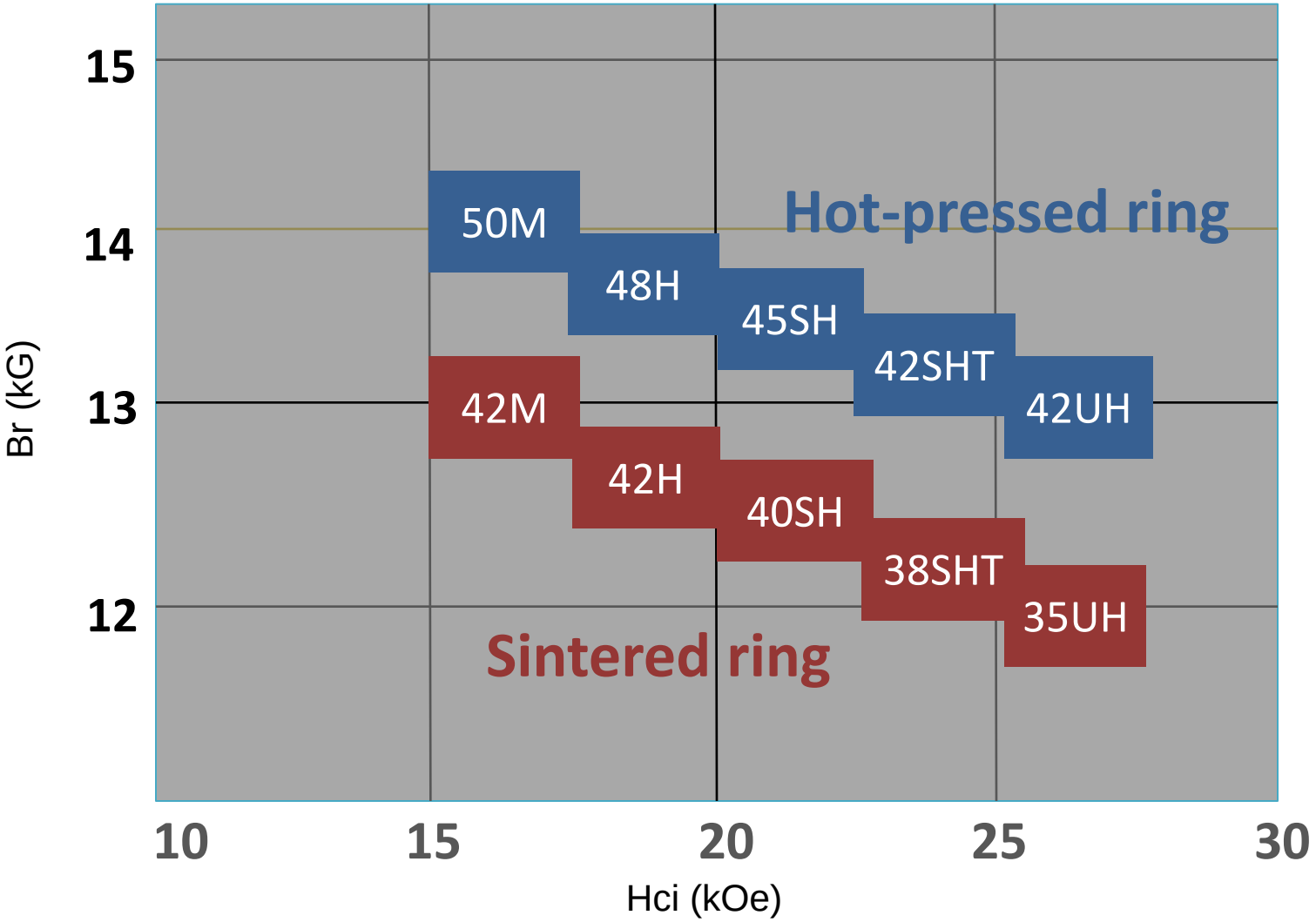


Smaller size

Various sizes of HP rings

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

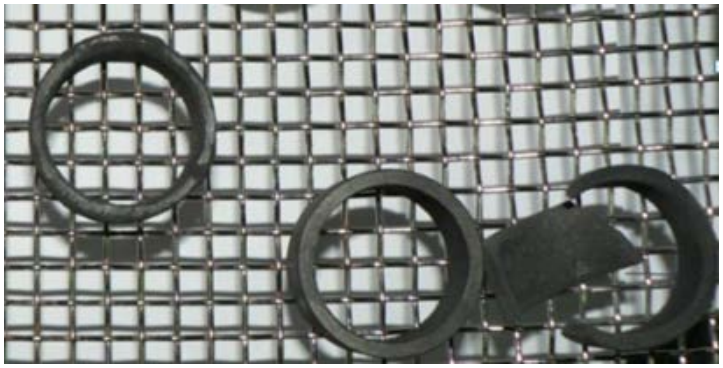
Magnetic Properties of Ring Magnets



Physical Properties of Ring Magnets

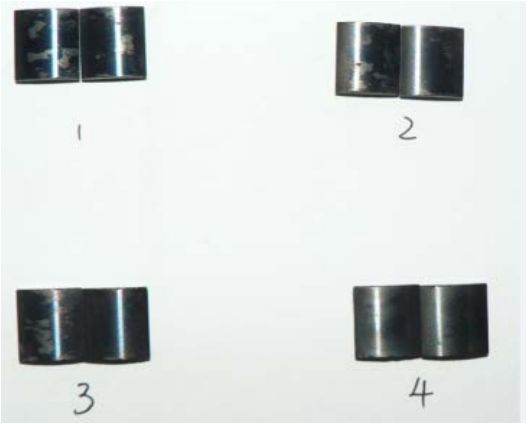
	Magnet-Nr.	nominal	tolerance	M6	M7	M8	M9	M10
measurement before test start	visual inspection							
	outer diameter [mm]	26.60	+0.1	26.65	26.64	26.64	26.65	26.65
	inner diameter [mm]	22.00	±0.05	22.02	22.01	22.02	22.03	22.02
	thickness [mm]	12.10	±0.1	12.05	12.09	12.09	12.09	12.10
	Surface [cm²]	21.986		21.964	22.016	22.013	22.022	22.041
	Mass [g]			15.8369	15.8315	16.1266	16.0734	16.0988
	Density [g/cm³]	7.50		7.43	7.40	7.55	7.53	7.52
	start value 100%			100.00	100.00	100.00	100.00	100.00
surement after HAST	visual inspection							
	Mass [g]			14.3896	15.5343	14.4096	16.0654	16.0552
	weight loss in %			9.14	1.88	10.65	0.05	0.27
	weight loss in mg / cm²			65.8934	13.4990	77.9984	0.3633	1.9782

Sintered ring



	Value	# 1	# 2	# 3	# 4	# 5
before HAST	Visual inspection	OK	OK	OK	OK	OK
	Diameter outer [mm]	26.65	26.66	26.66	26.66	26.65
	Diameter inner [mm]	22.03	22.04	22.05	22.04	22.03
	Thickness [mm]	12.16	12.18	12.18	12.06	12.14
	Volume [cm³]	2.15	2.15	2.15	2.13	2.14
	Surface [cm²]	22.13	22.17	22.17	21.99	22.10
	Mass [g]	16.3139	16.1931	16.2540	16.2413	16.3606
	Density [g/cm³]	7.60	7.52	7.57	7.62	7.63
after HAST	Visual inspection	OK	OK	OK	OK	OK
	Mass [g]	16.3074	16.1901	16.2521	16.2380	16.3583
	Weight Loss [%]	0.04	0.02	0.01	0.02	0.01
	Weight Loss [mg/cm²]	0.29	0.14	0.09	0.15	0.10

Hot-pressed ring



Hot Press parts have superior corrosion resistance to sintered magnets

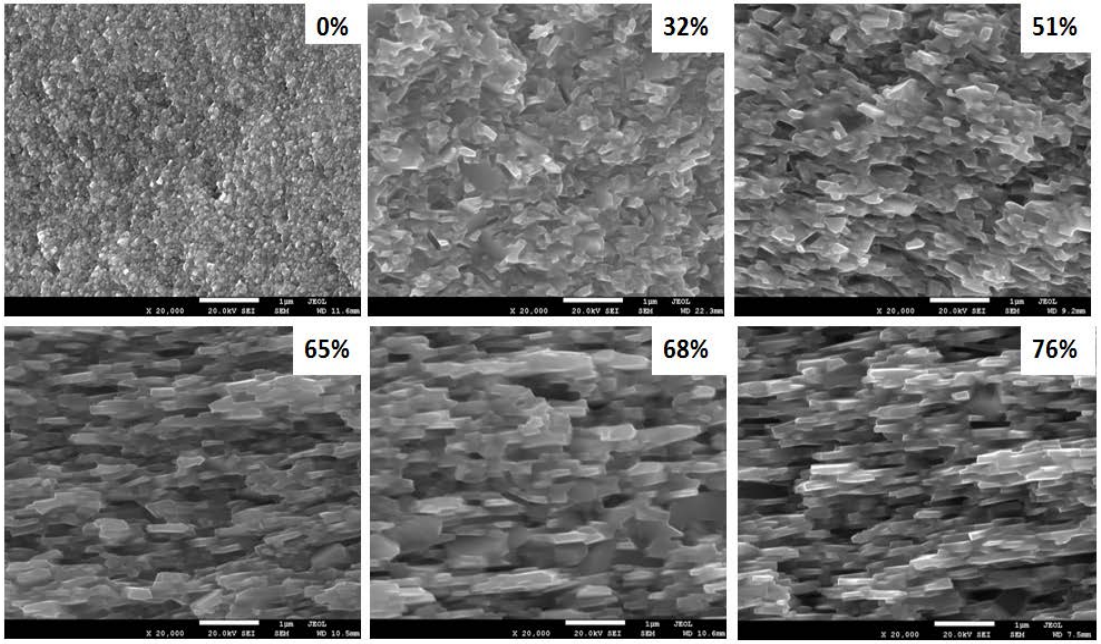
Comparison of Radially Oriented Sintered to Hot Pressed Magnets

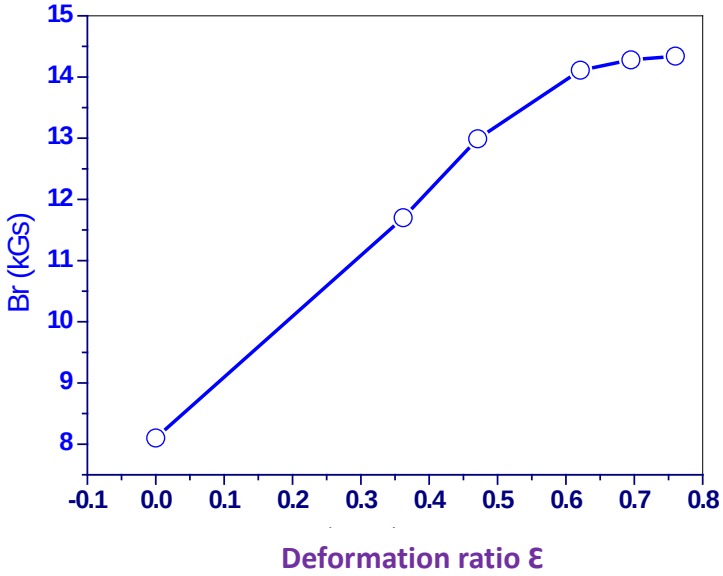
Item	Sintered ring	Hot-pressed ring
Surface magnetic flux waveform	Rectangular wave	Rectangular wave
Number of poles	Variable by magnetization	Variable by magnetization
Magnetized position	Variable by magnetization	Variable by magnetization
Skew magnetization	Yes	Yes
Recommended inside-to outside diameter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

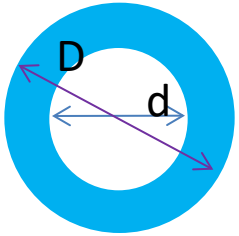
Hot Pressed Magnetic Properties

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







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

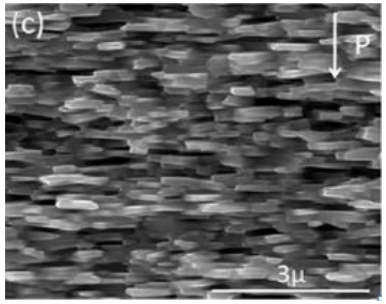
Higher deformation ratio leads to a higher alignment degree.
The deformation ratio can determine the remanence of hot-deformed ring.

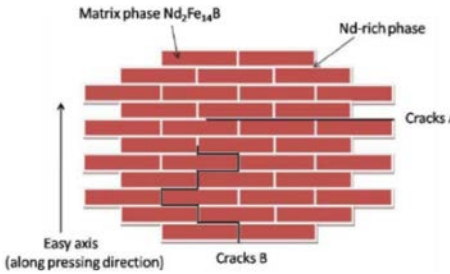
Temperature & Physical Properties

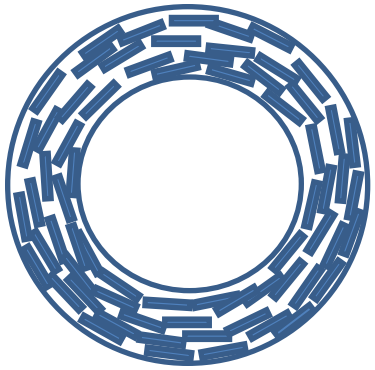
	Unit	
Temp. Coefficient of Br α	%/℃	-0.10
Temp. Coefficient of Hci	%/℃	-0.50
Recoil Permeability		1.05
Magnetizing Force	T	2.5
Density		7.6~7.7
Curie Temperature	℃	360
Specific Heat	J/Kg℃	550
Thermal Conductivity	W/m℃	4.80
Thermal Expansion Coefficient (20～200℃)	×10-6/℃	radially 1～2
		axial -1～0
Electrical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

Comparison of Mechanical Properties

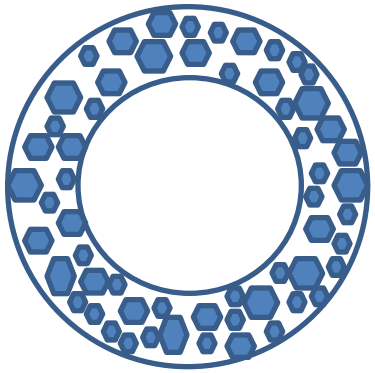
	Fracture toughness （MPa·m-1/2）	Bending strength （MPa）
Sintered ring	4~5	150~200
hot-pressed ring	6~7	~400







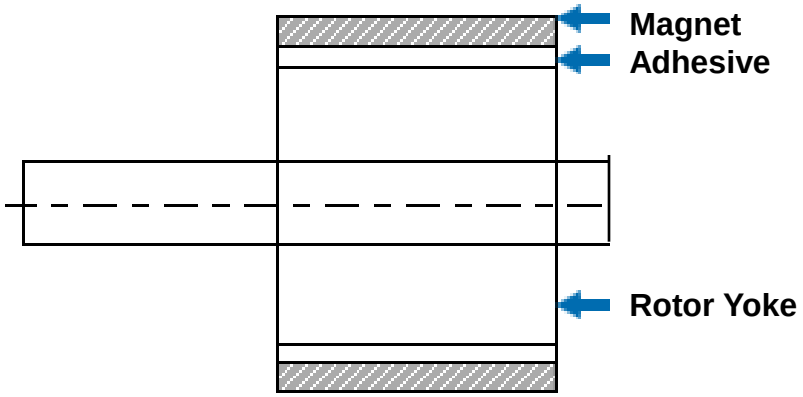
Grains in hot-deformed ring



Grains in sintered ring

Thermal Expansion Coefficient
(20～200℃)

Example of inner rotor design

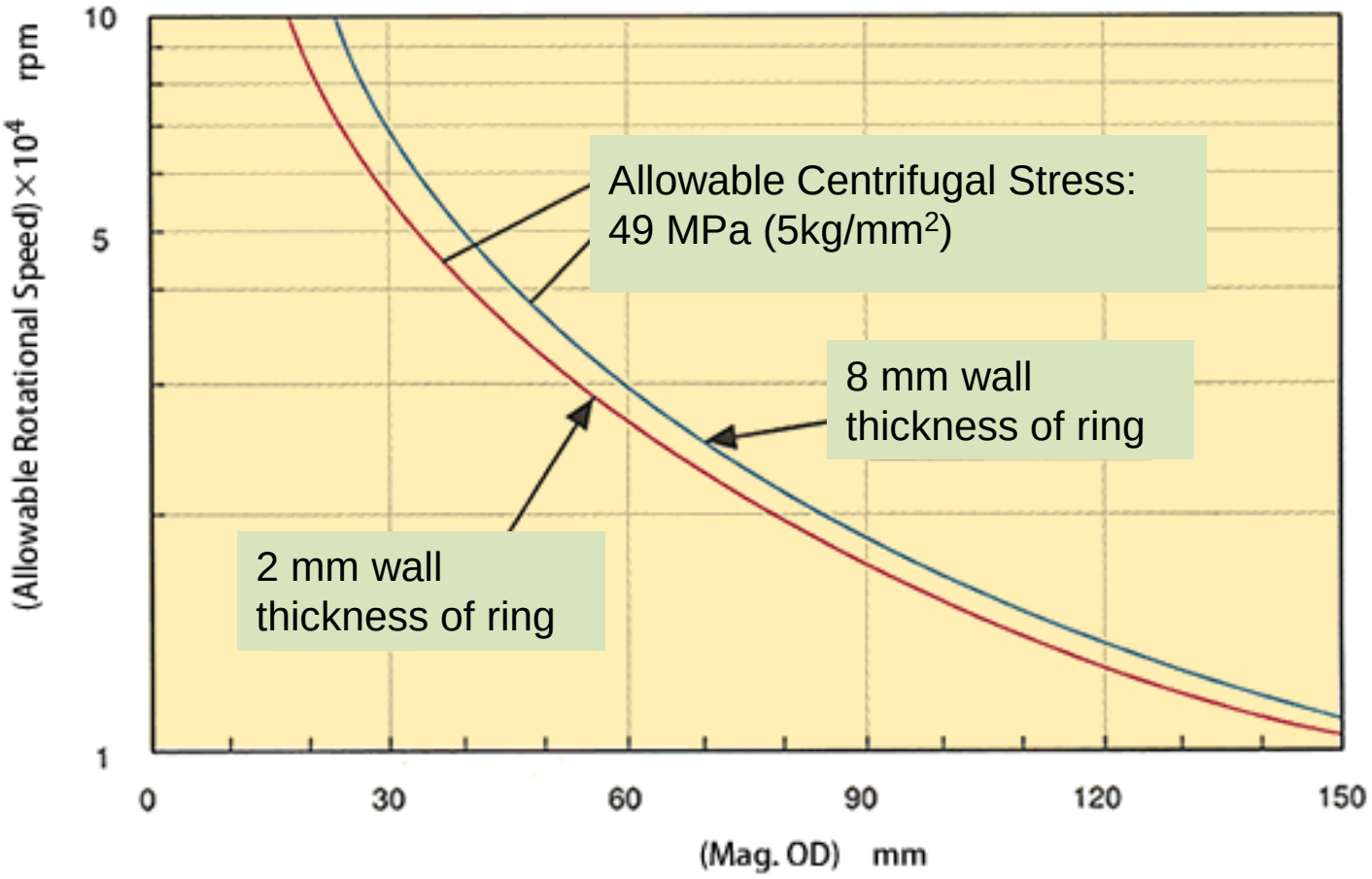


(Thermal Expansion Coefficient of Rotor Parts)

Radial ring	$1\sim2\times10^{-6}$
Rotor Shaft S45C	12×10^{-6}
Adhesive	$50\sim100\times10^{-6}$

(-30～200℃)

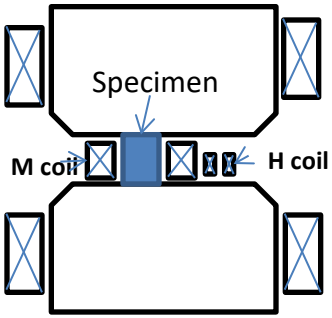
Allowable Rotation Speed

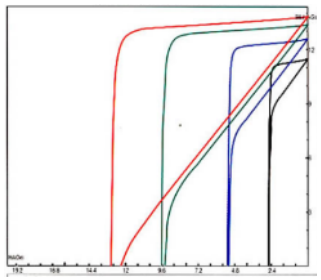


Magnetic Properties Testing

B-H Curve
1 piece/lot

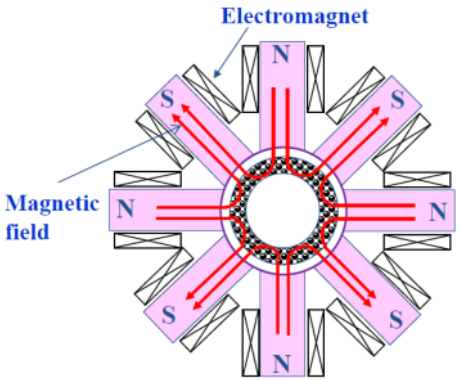
1. A few rectangular specimens are cut from a ring magnet.
2. Fully magnetized by pulse field.
3. Measure by B-H tracer.





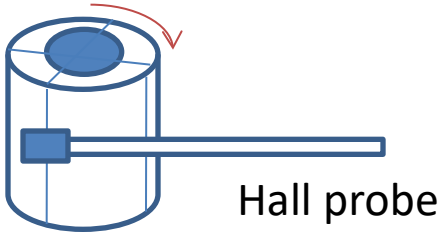
Magnetic Flux
2~20 pieces/lot

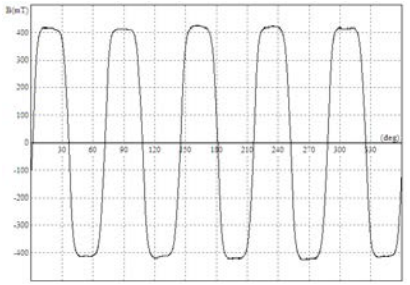
1. Machined ring magnets are magnetized in a multi-pole magnetizing fixture.
2. Measured flux in the fixture by a flux meter.



Surface Flux Density
2~20 pieces/lot

1. Machined ring magnets are magnetized in a multi-pole magnetizing fixture.
2. Measured by gauss meter.

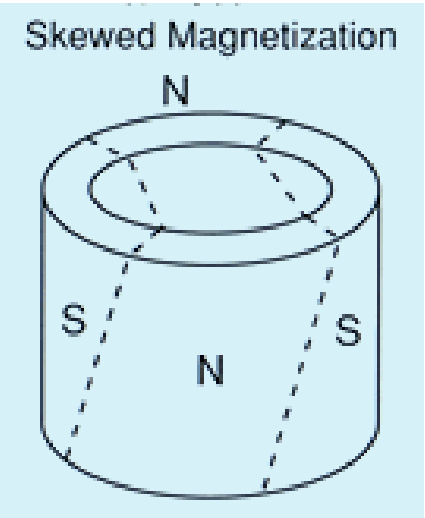


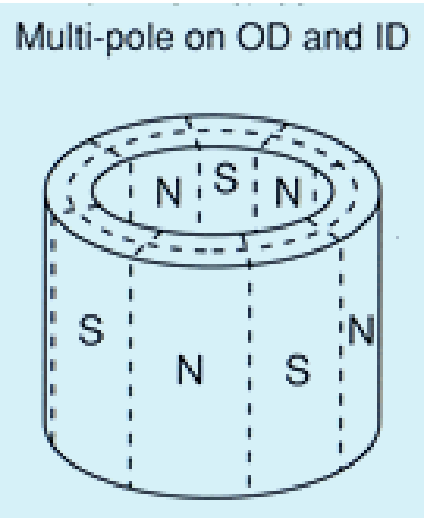


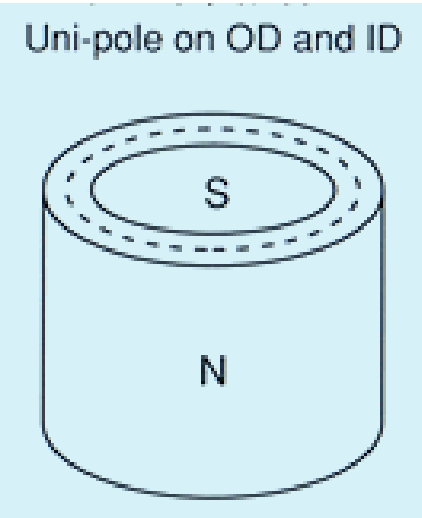
Plating & Coatings

- Epoxy
- Ni，Ni-Cu-Ni，NiCuNi+Cr
- Zn，Sn
- Passivation
- Everlube
- Teflon
- Aluminum

Magnetization of Ring Magnets

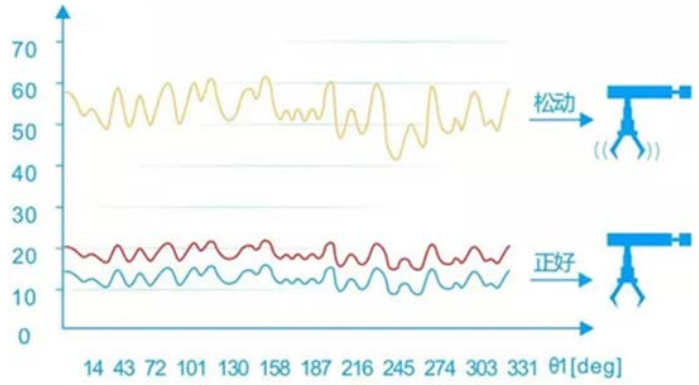




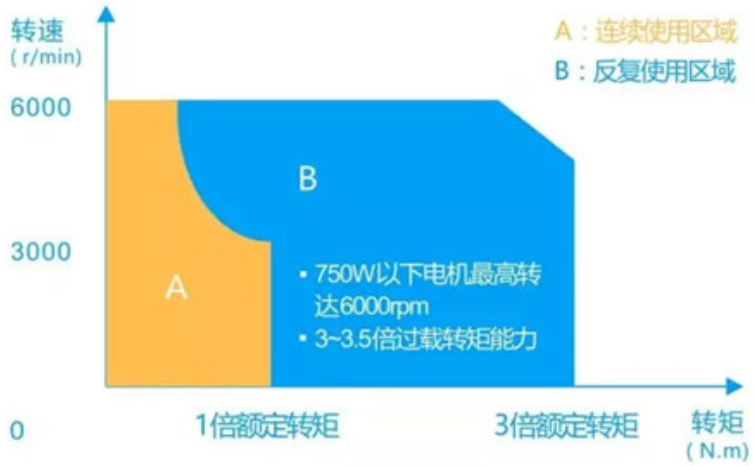


Type	Skewed multi-pole	Muti-pole	Uni-pole
Application	Servo motor Electric Steering Low-cogging motor Magnetic geared Specialty motors	Servo motor Generator Compressor	Linear actuator Compressor Magnetic bearing Audio

Servo Motor Applications



Low cogging torque



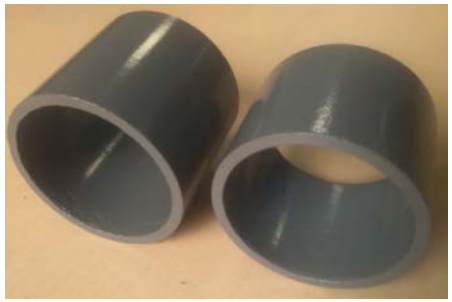
（1）Ultra low cogging torque, accurate positioning.

（2）wide operating range and high overload capacity, stable operation

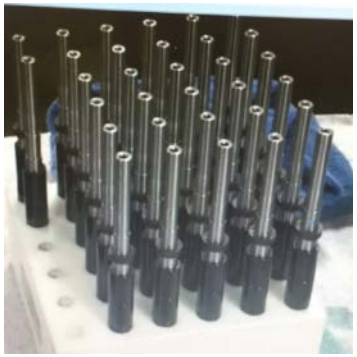
（3）excellent temperature rise characteristics, safe and reliable

（4）quick response, to achieve maximum speed of 6000rpm, only about 5 milliseconds

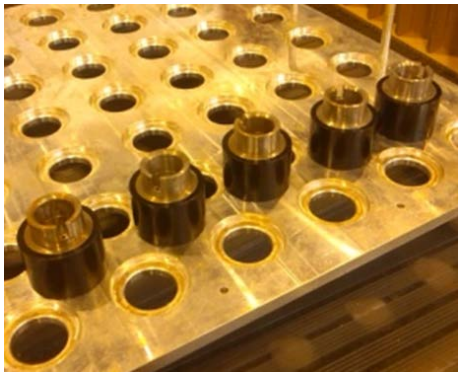
Automotive Motor Applications



EPS



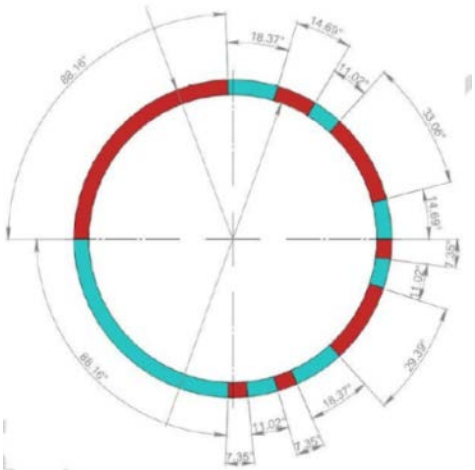
Seat Motors

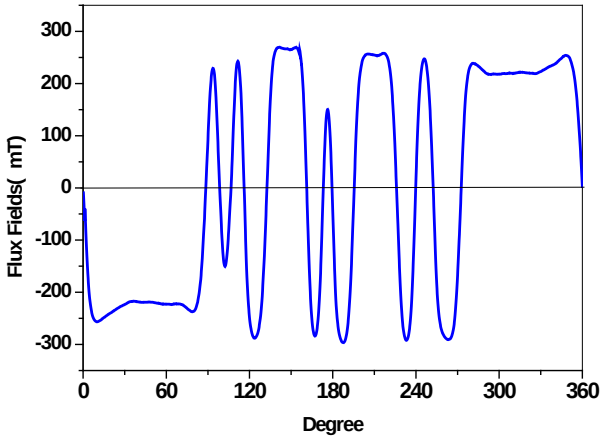


Exhaust Valves

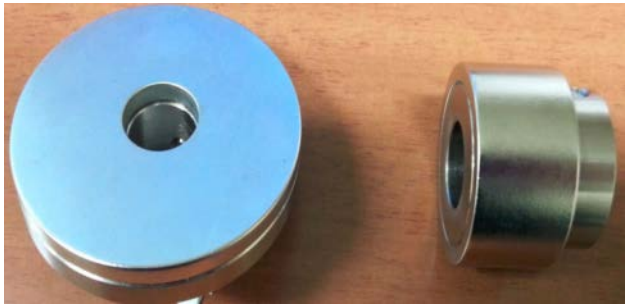
- Electric Power Steering
- EGR Valves
- Seat Motors
- Pumps

Other Applications





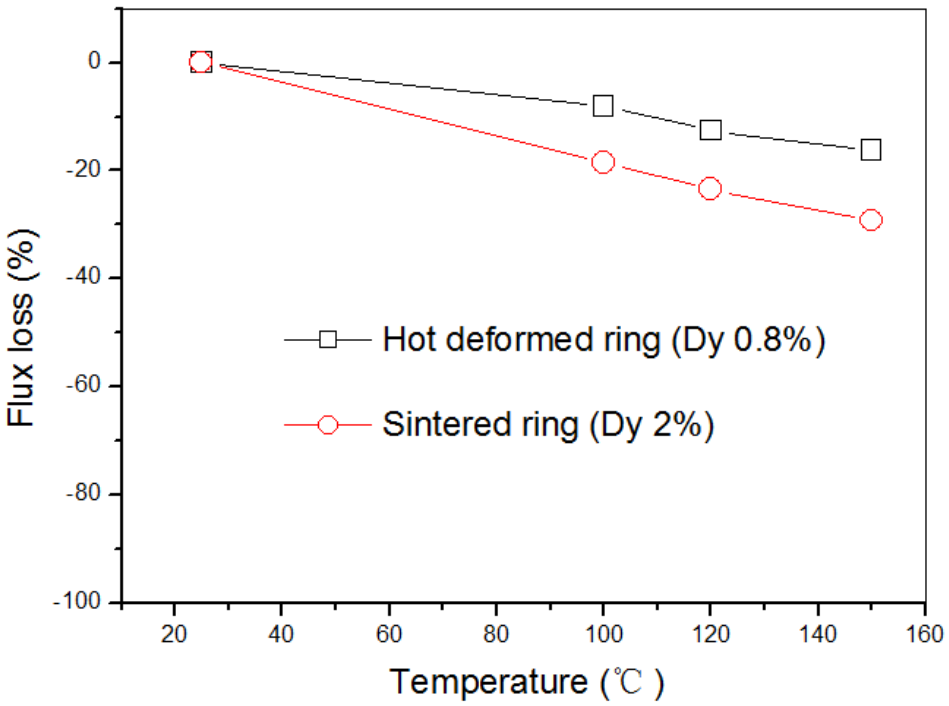
Magnetic Encoder



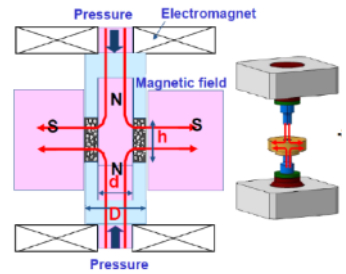
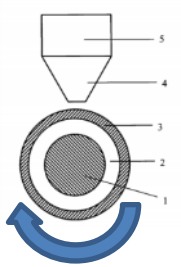
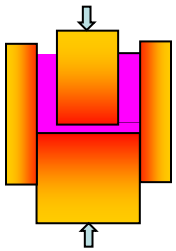
Magnetic gear

Linear motor:
Portable refrigeration

Less Heavy Rare Earth Content



Overall Comparisons

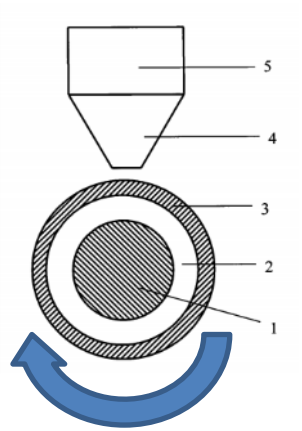
	Pressing	Magnetic properties	Magnetic angle deviation	Corrosion resistance
sintered ring	 magnetic repulsive	poor	0°	poor
	 Rotation	good	poor (15~25°)	poor
hot-pressed ring		better	0°	good

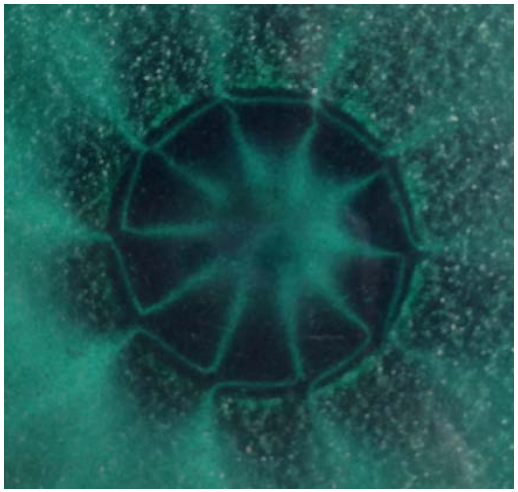
Magnetic Angle Deviation

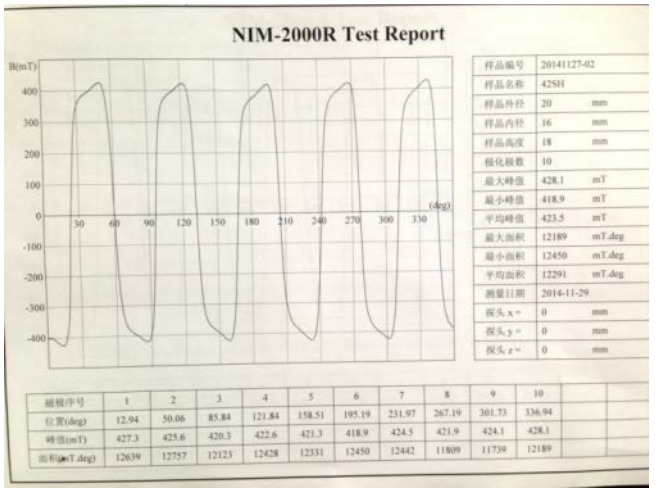
Size	Pressing Method	1	2	3	4	average
D39.35*D32.5*27	Hot-pressed	0.52°	0.38°			0.45°
D39*D30*25.5	Rotation sintered	14.55°	13.92°	12.55°	14.66°	13.92°
D14*D10*20	Rotation sintered	22.44°	24.68°	22.89°	22.96°	23.24°
D30*D24*20	Rotation sintered	18.39°	18.41°	15.87°	14.36°	16.75°

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

Magnetic Angle Deviation

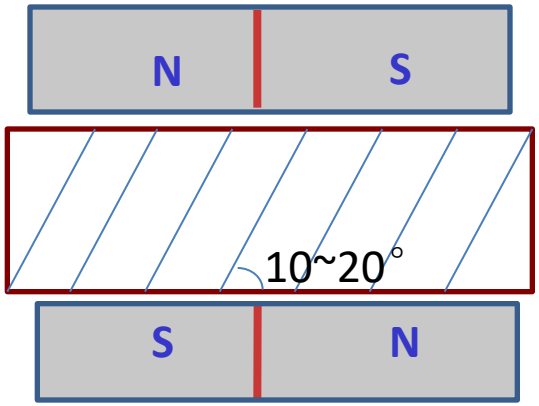




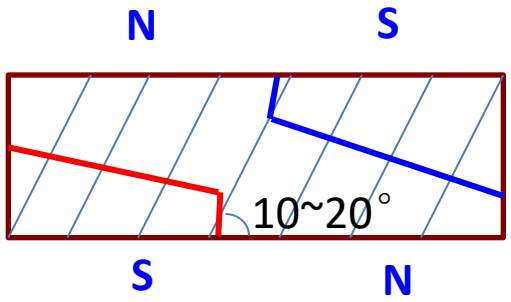


Magnetization

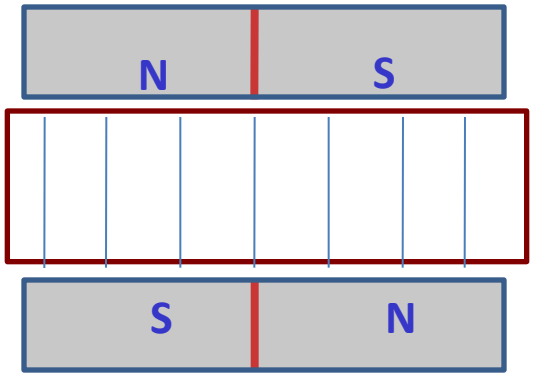
After Magnetization



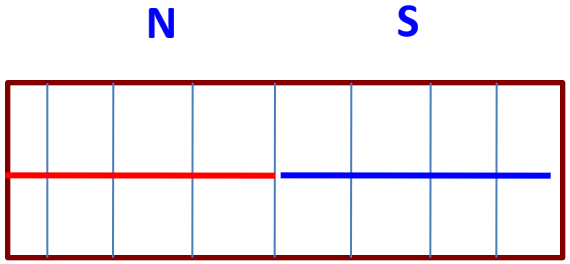
Magnetic angle deviation 10~20°
(Sintered ring)



Tiled boundary of N/S
（sintered ring）

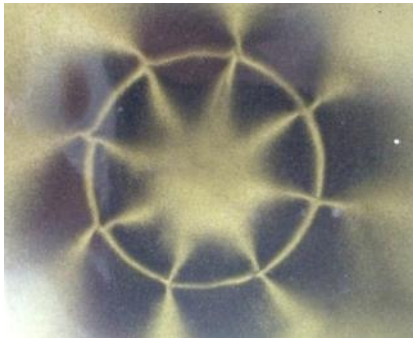


Magnetic angle deviation 0°
(Hot-pressed ring)

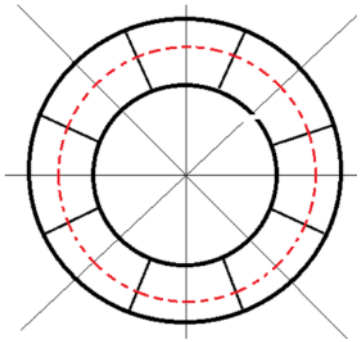


Parallel boundary of N/S
(hot-pressed ring)

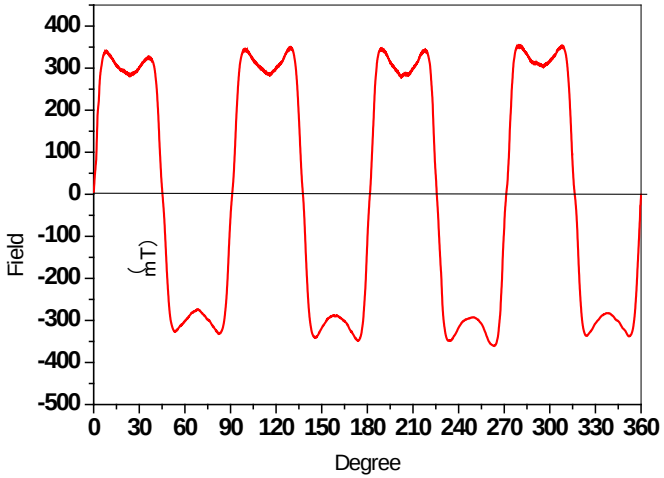
Radial vs Rotational Alignment



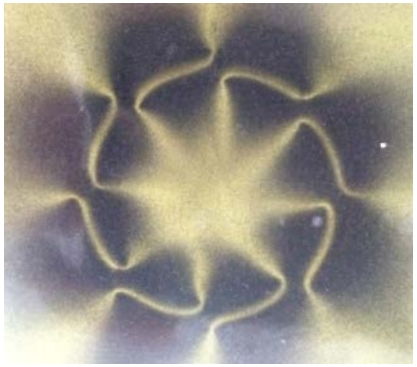
Radial
（hot-pressed ring）



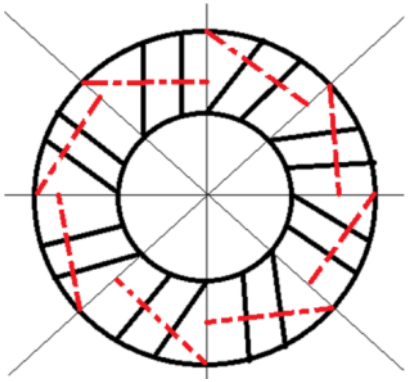
Alignment



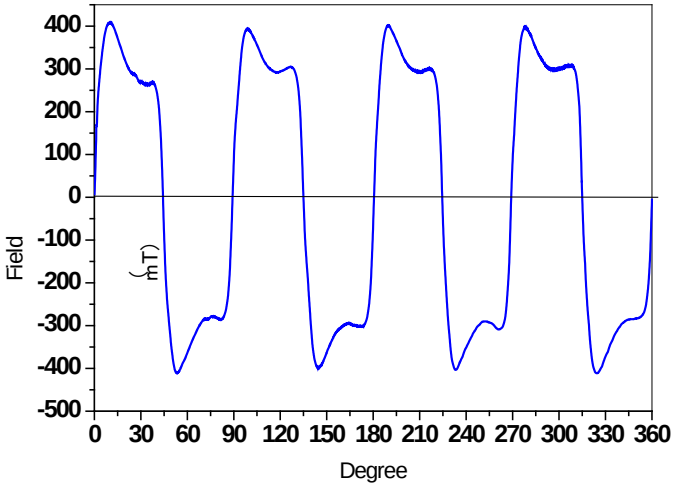
Wave Form



Rotating
（sintered ring）

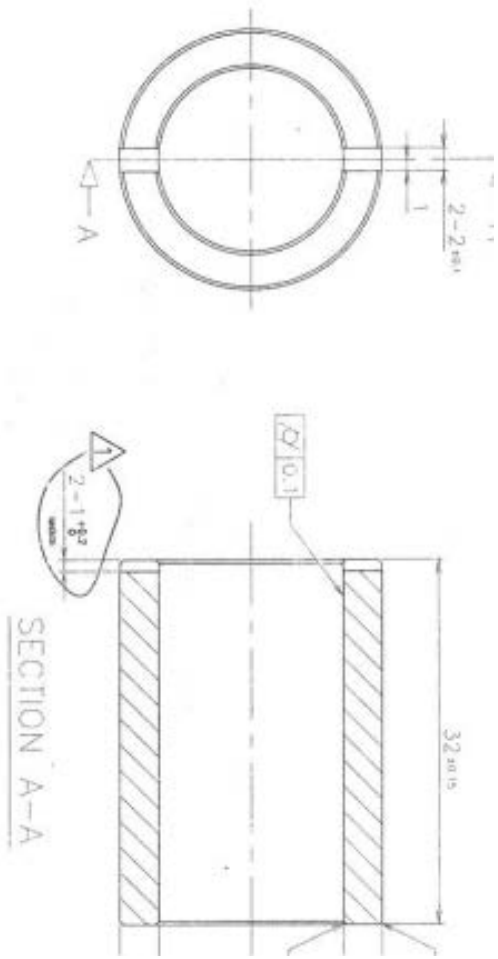


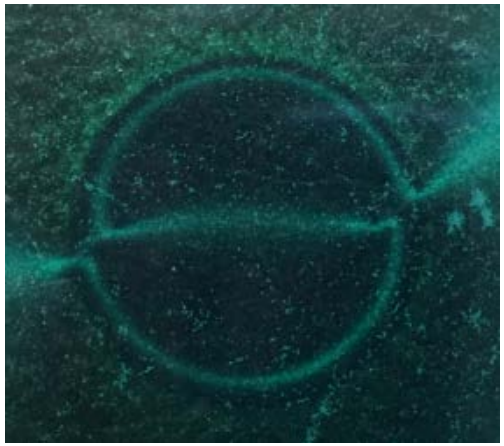
Alignment



Wave Form

Defect of rotation pressing of sintered ring





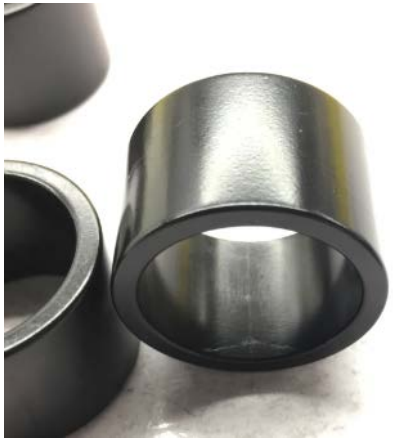
N/S boundary deviation（~7°）

For high precision valve motors, the rotation pressing of a sintered ring is unacceptable.

Cracking issues with sintered rings

Crack during pressing

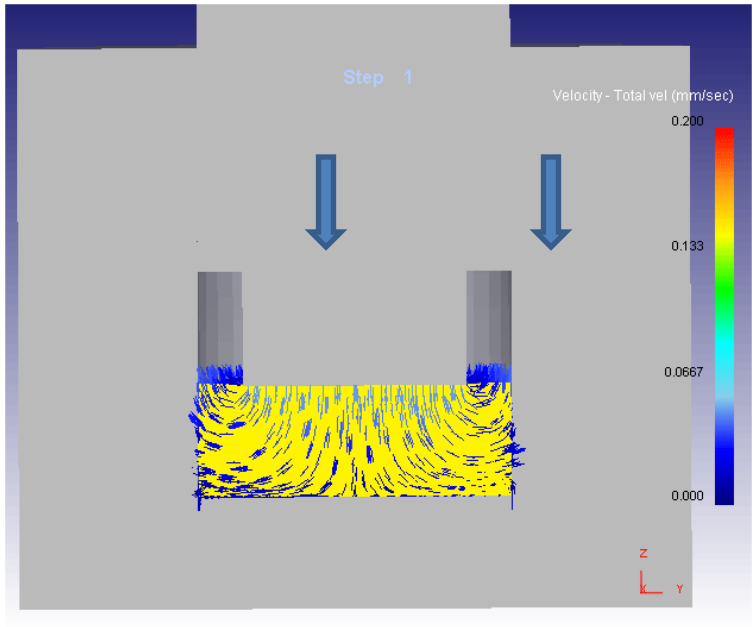
Crack after sintering

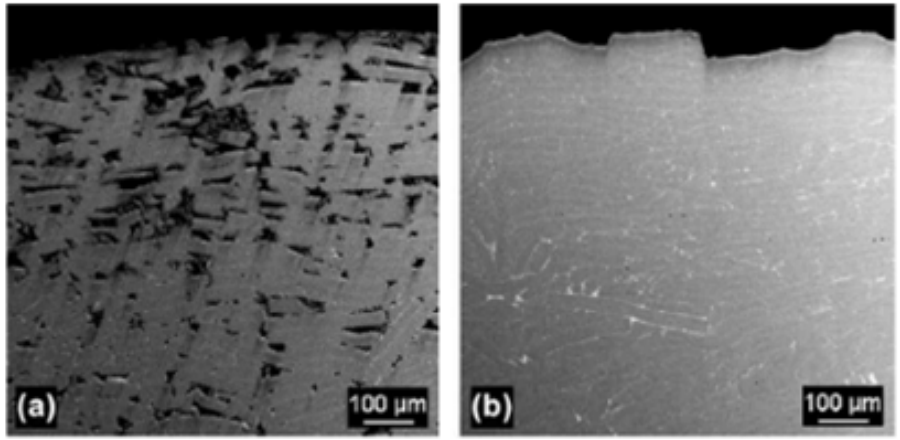


Crack after coating

The inevitable internal stress will lead to the cracking of the sintered rings.

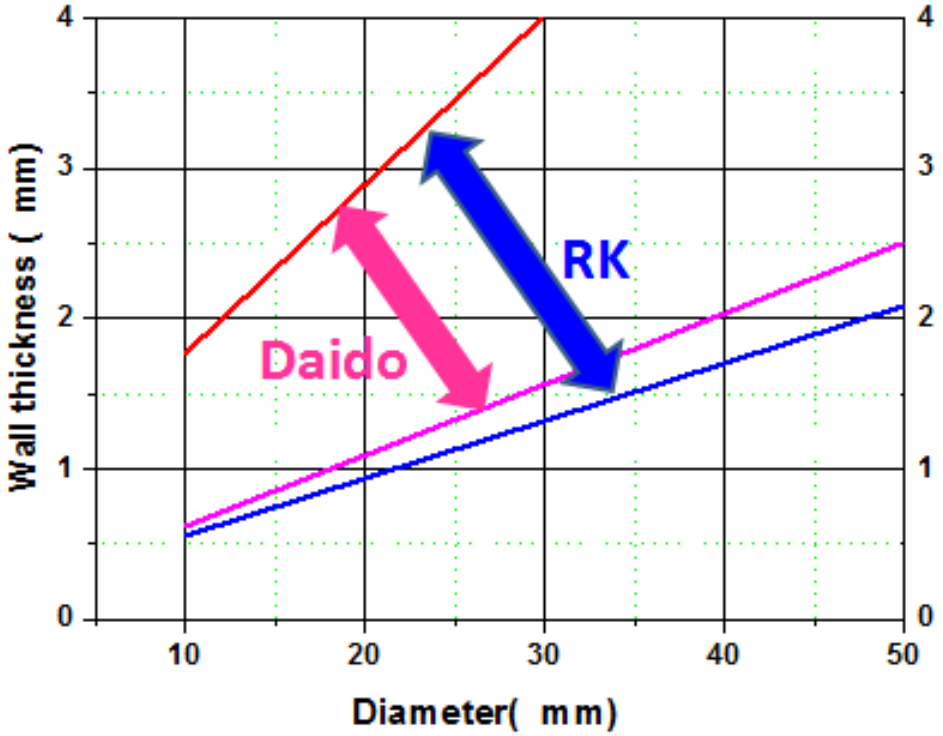
Better Mechanical Strength





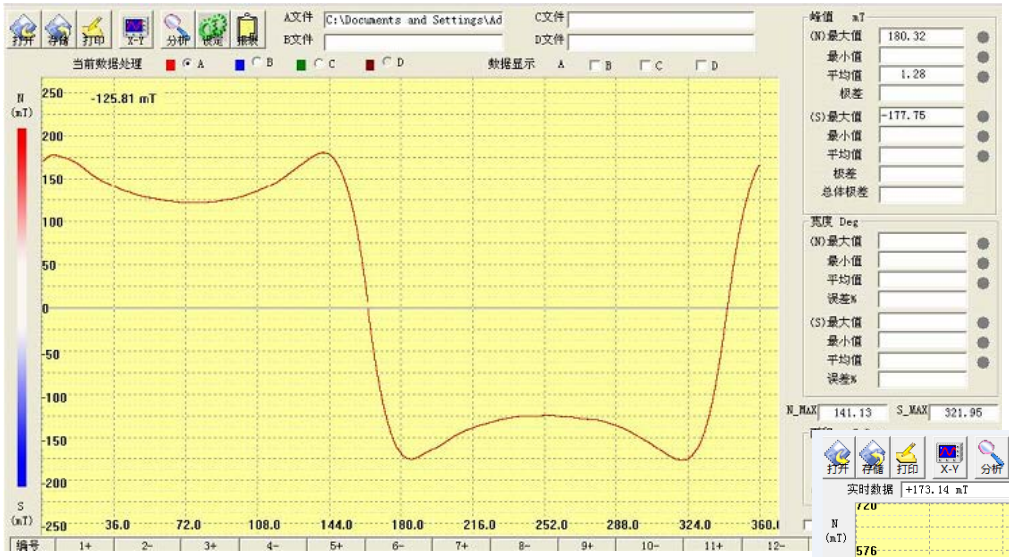
Supply of additional back pressure on free surface help to get crack-free and mechanical stronger ring.

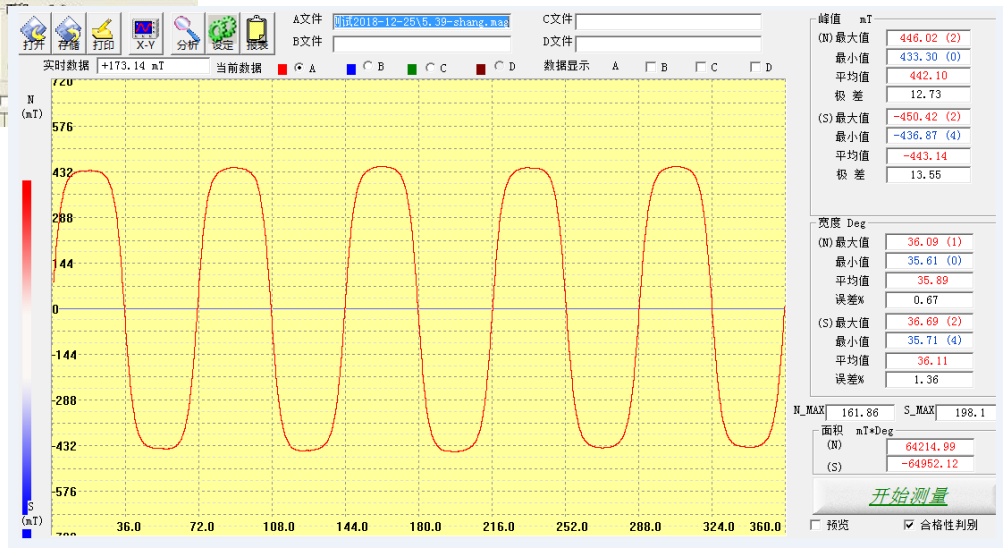
Thin-wall thickness



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

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