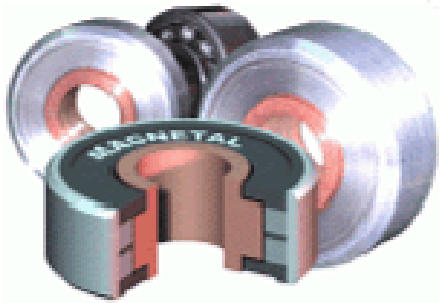
Magnetal has patented solutions for unique passive magnetic bearings that enables- and improves high speed operation

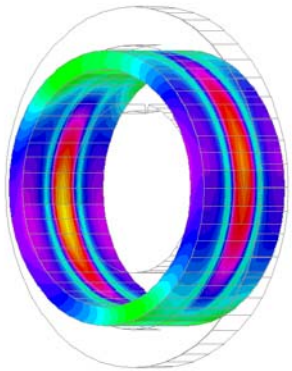
Technology Presentation - Level 2

Turbo Molecular Vacuum Pump

Technology Advantages

Compared to Ball Bearings





Single row intermediate bearing for hollow shafts

Double row intermediate bearing for hollow shafts

Quad row external magnet bearing for solid shafts

- Noise & vibration free
- Lubricant free
  - cleaner vacuum
  - simpler design
- Maintenance free
- Cost effective
  - in production as well as in service
- Extremely low friction - no abrasion
- Less alignment sensitive
- Ultra high performance

Technology Advantages

Compared to Active Magnetic Bearings

Single row intermediate bearing for hollow shafts

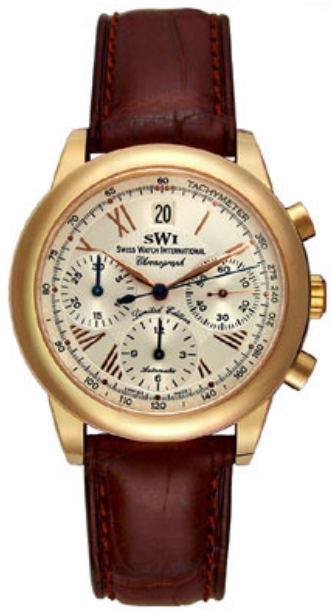
Double row intermediate bearing for hollow shafts

Quad row external magnet bearing for solid shafts

- Lower friction
  Lower rotational losses
- No control noise
  Silent operation
- Simplistic design
  No control electronics required
- Smaller footprint
  Weight & volume
- Maintenance free
- No lubricants required
- Totally sealed design possible
- Cost effective
  Production & service

How small can we make the bearings?

- Generally magnetic bearings does not require as small diameters as ball bearings – but if desired we can make them in the size to fit a Swiss watch
  (equal to - or less than - one mm in diameter.)
- Size depends on the loads. Our solution can help reduce the loads and thus reduce dimensions.
  Force corresponds to exposed surface
- If the bearing load is found to be too high we can also provide magnetic unloading devices



Swiss Watch

(Often fitted with magnetic devices in the mm range)

Increase in weight?

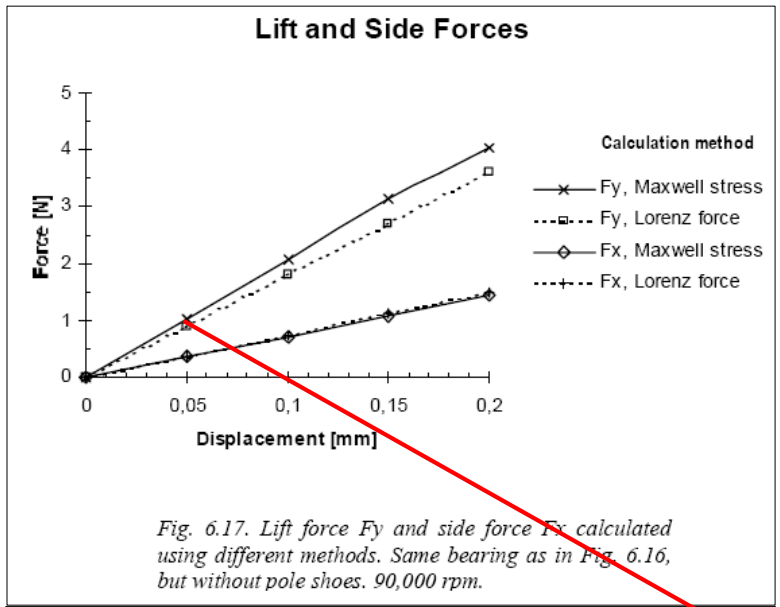


Fig. 6.17. Lift force Fy and side force Fx calculated using different methods. Same bearing as in Fig. 6.16, but without pole shoes. 90,000 rpm.

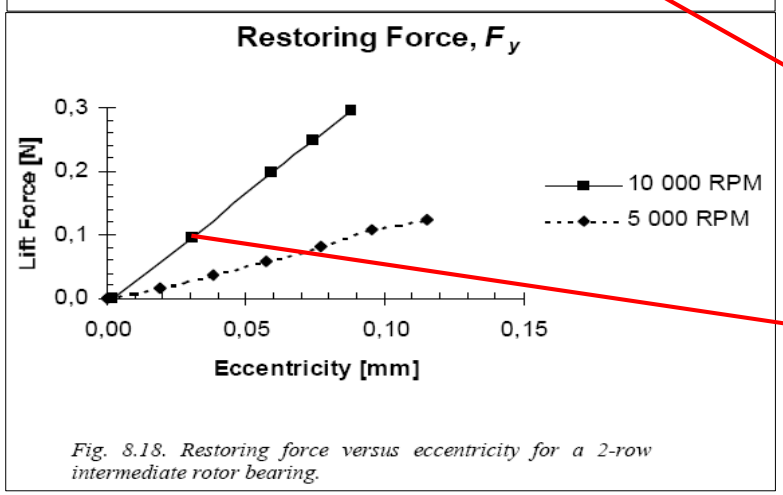


Fig. 8.18. Restoring force versus eccentricity for a 2-row intermediate rotor bearing.

"How much will the rotor be displaced if it is contaminated and thus impacted with weight?"

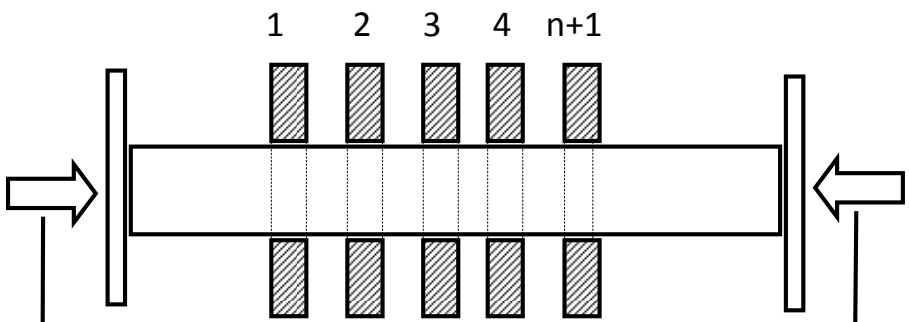
It depends on the amount of contamination and build up, but in general 1-3 μm.

Examples:

90.000 RPM
1N => 0,05 mm, 1 gram => 0,0005 mm

10.000 RPM
0,1N => 0,03 mm, 1 gram => 0,003 mm

5 Axis passive system
How is it possible?



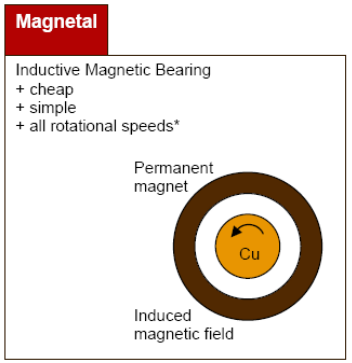
Radial
(Preferably built in dampers)

Axial – preloaded
(Preferably built in dampers)

5 axis passive operation is possible by:

- For instance add two axial bearings preloaded towards each other and then at least two radial bearing to carry the radial forces.
- Damping can devices are added according to rotor dynamic simulations
  (Magnetal offers integrated solutions)

Radial Loads
How much



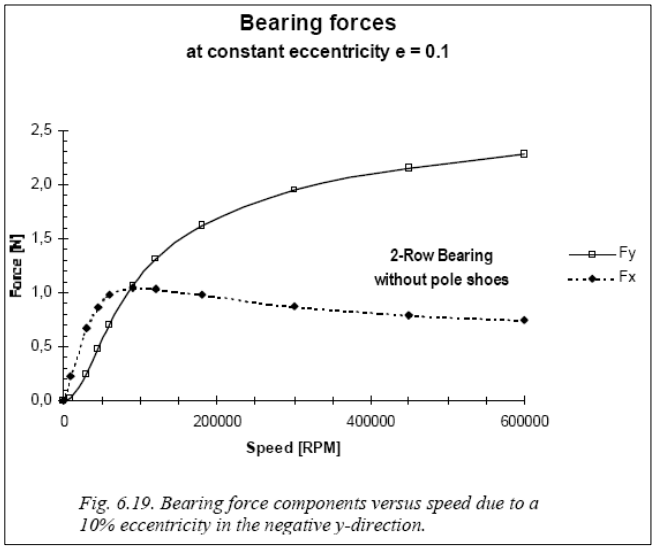


Fig. 6.19. Bearing force components versus speed due to a 10% eccentricity in the negative y-direction.

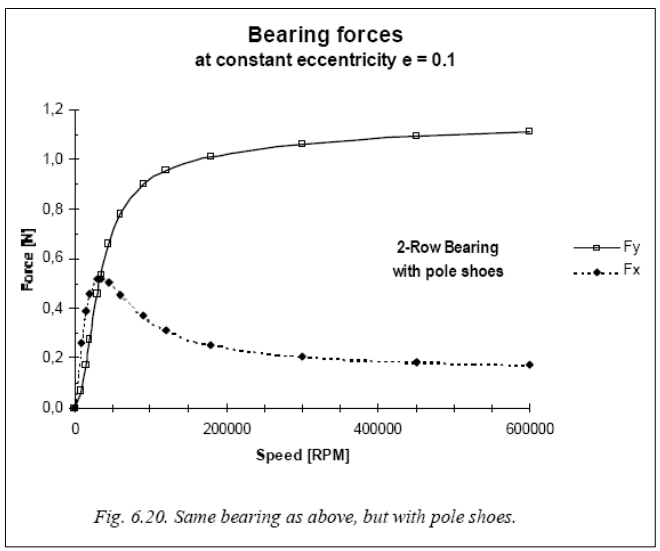


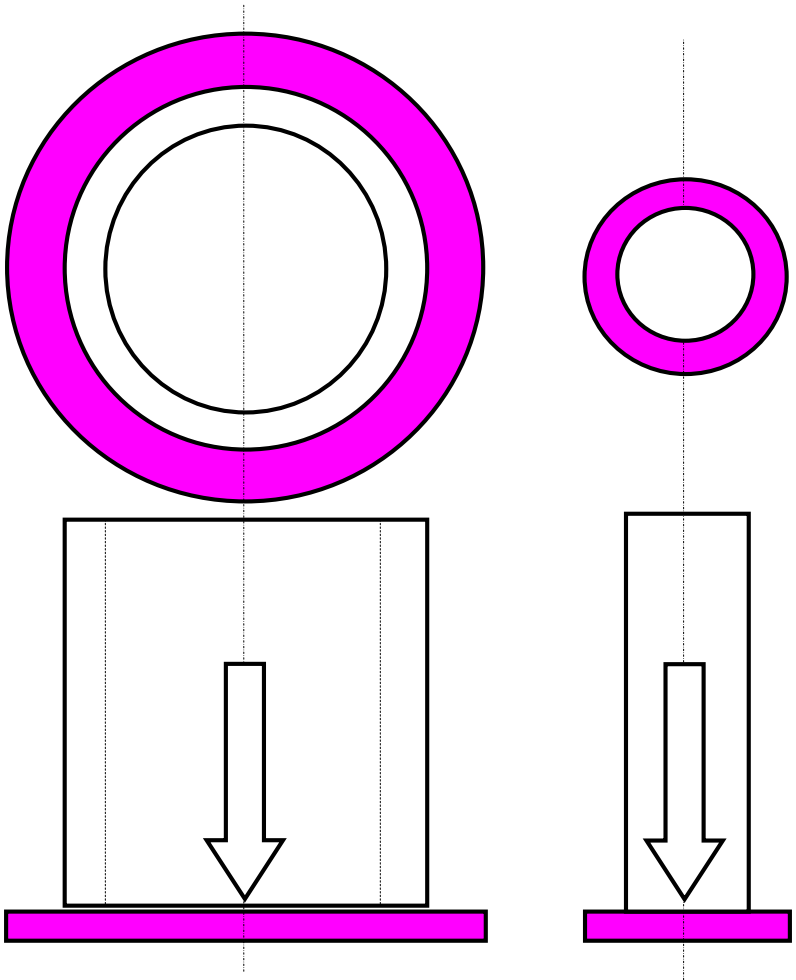
Fig. 6.20. Same bearing as above, but with pole shoes.

10% eccentricity (10 of load capacity used)

Radial loads;

- Generally - higher RPM is enabling our radial bearing to carry more load depending on an increase in induced current. The increase in induced current will provide a larger reposition force.
- *A new product is under way (Gen 3) that is rpm independent
- Our current passive magnetic bearings will take off at about 15 000 rpm and will continue to increase stability with increased rpm. The take off will on rpm vs. load levels.

Axial Loads
How much



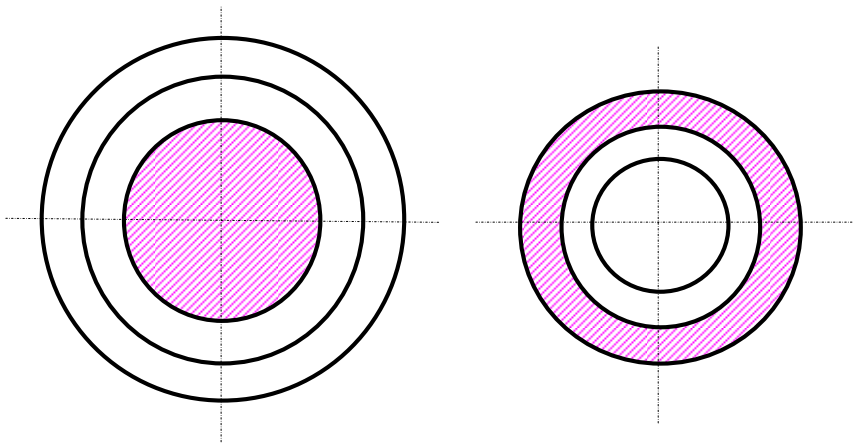
Better characteristics
Loads, Momentum, Weight

Less optimum solution
Poorer characteristics due to smaller circumferential area

Axial loads;

- In this application a regular Axial PMB will be used and harmonized with the radial bearings.
- Axial loads are dependent on the circumferential area of the bearing and not the RPM
- This means that a large thin walled shaft is a benefit to the construction vs. a regular solid shaft.
- Increase in axial load will also require stronger radial bearings since instability may otherwise appear

Shaft design



- Better strength/weight ratio
- Better capability to transfer torque
- Larger circumferential area that positively impacts the passive magnetic bearing axial load capability
- Also radial exposed area towards radial passive magnetic bearings increases and increases load capacity

To increase performance a shaft should considered to be;

- A thin walled hollow shaft will increase the weight/strength ratio (requiring smaller/cheaper bearings) Rotor dynamic characteristics are also improved.
- Increased diameter will positively affect the axial bearing load capacity and will also impact the area for radial magnets since an internal stator – rather than an - an external can be used.
- A thin walled cylinder can be used as a Holweck
- A hollow shaft also enables the use of intermediate bearings adding performance.

Stiffness

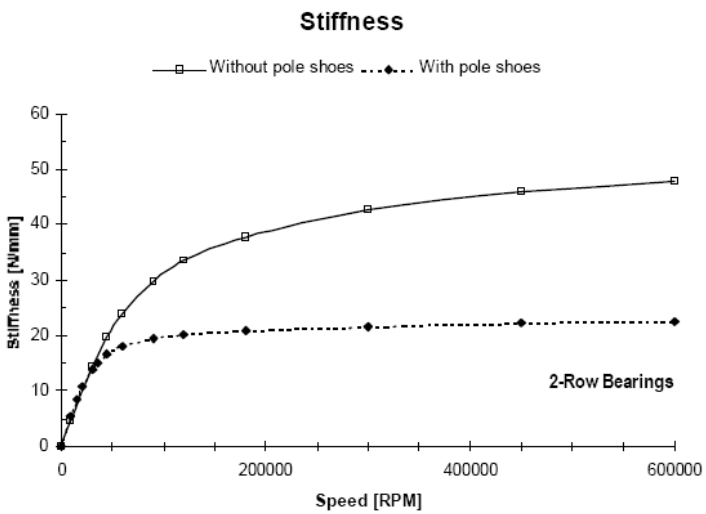


Fig. 6.23. Comparison between stiffness for the bearings in Fig. 6.19 and Fig. 6.20.

In Fig. 6.17-6.20 we have studied how the x and y- components of the bearing force and the losses relates to displacement and to speed. In the speed calculations the displacement was set to 0.05 mm, which corresponds to an eccentricity ε of 10%. We are now able to make some conclusions:

Stiffness:

- The stiffness component can be completely detached from the load component.
- Stiffness is speed dependant in the same way as conventional hydrodynamic bearings
- All bearing characteristics, such as stiffness and cross coupling, needs to be determined with rotor dynamic calculation- & simulation tools

Damping

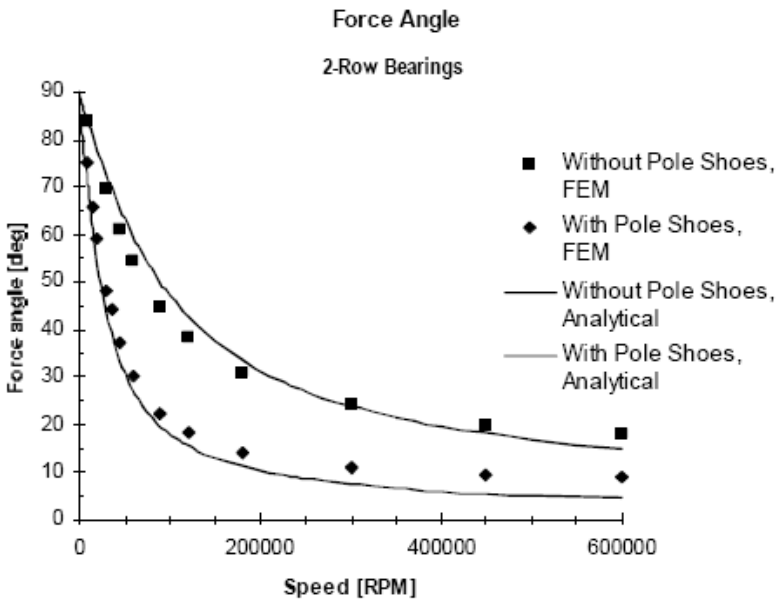


Fig. 5.25. Corresponding force angle for the bearings in Fig. 5.24.

Damping needs to be added.

Damping:

- Needs to be determined with rotor dynamic calculation simulations
- It is possible to add separate viscous- or eddy current dampers to the construction.
- We also provide build in dampers

Take off

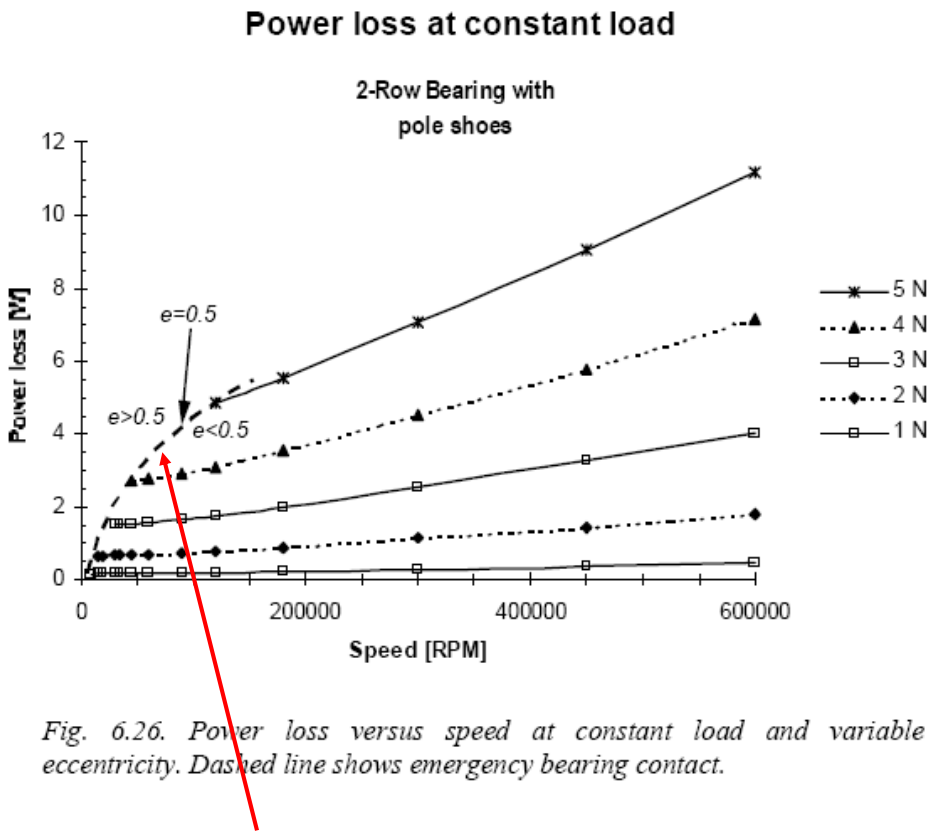


Fig. 6.26. Power loss versus speed at constant load and variable eccentricity. Dashed line shows emergency bearing contact.

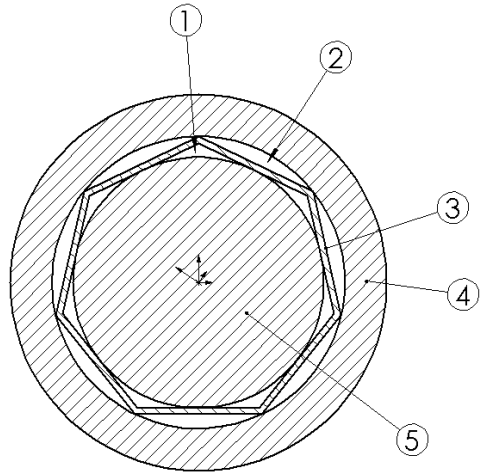
e=0,5 equals take off speed.
Take off speed different depending on loads [1..5N]

Take off;

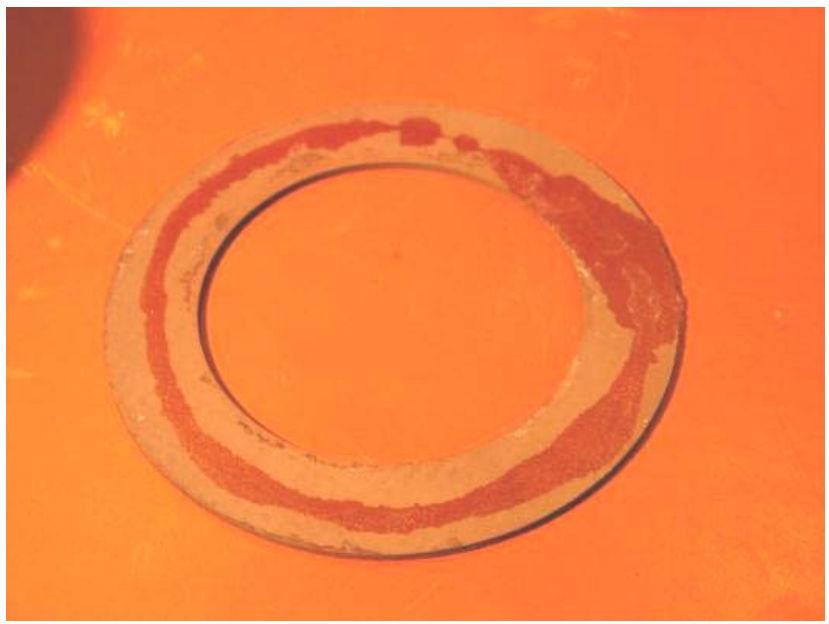
- If correctly designed take off can be enabled instantaneously for an axial oriented bearing
- Radial oriented bearings are rpm dependant and around 15 000 rpm they will take off (see diagram left)
  The take off RPM is depending on load factor.
- We are currently into developing a generation 3 bearing that are RPM independent

Touch down

- During take off - integrated air foil bearings will support the rotor. These bearings are also used as emergency bearings (solutions patented by Magnetal)
- To increase life time in vacuum, where no air is present, the foil is released by the use of centrifugal forces..
- Optimization of magnetic bearings may be performed with regards to
  Touchdown, **R**adial loads or **T**ake off speed.
- Design of touch down solutions requires extensive rotor dynamic simulations. Factors to take into consideration are number of touch downs, speed at touch down, safety factors, material used, life time
- Magnetal is capable of offering an integrated total solution for touch down/emergency issues.
- Instead of foils, conventional touch down ball bearings may be used – but with less predictable results.



Corrosion issues



How about corrosion?;

- This is generally handled with investments in different coatings from Nickel to Gold plated if needed and motivated by cost vs. performance
- In more aggressive environments encapsulation may be required.
- Magnetal delivers completely encapsulated bearings on request, depending on type of corrosive media. For instance stainless steel, or titanium e t c may be used in more demanding environments.

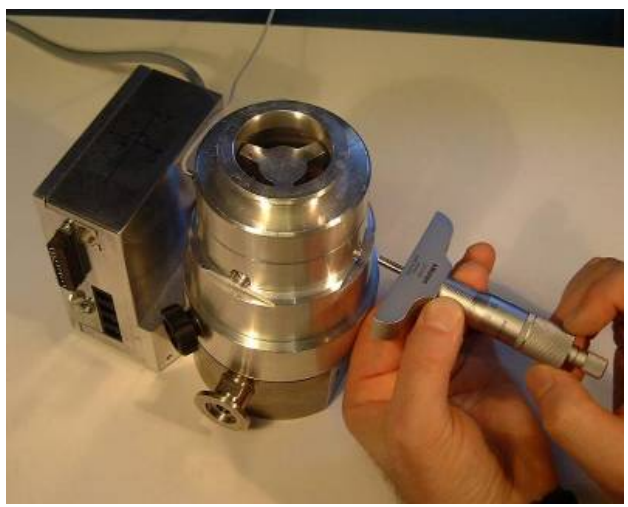
To give you a general idea of ready made Magnetal designs

Flywheel system with Motor/Generator

Intermediate bearing design

Motor design

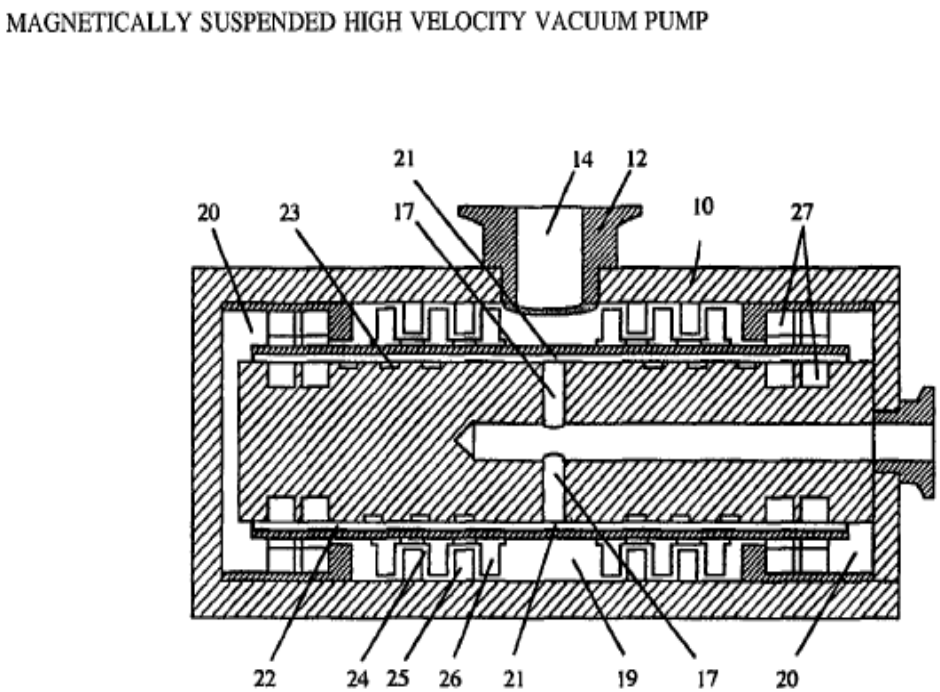
Magnetically levitated spindle unit with integrated drive



Real life solutions Vacuum

Real life solutions Flywheel, Motor, Spindle

Turbo Molecular Vacuum Pump



Picture from Magnetal patent

New Pump Concept

- Magnetal has proposed a new concept for small – low cost – fully passive magnetic turbo molecular pumps
- Double flow design incorporating Holweck pump stages.
- The pump can be made very small and light weight yet cost effective.

What material is the rotor made of?

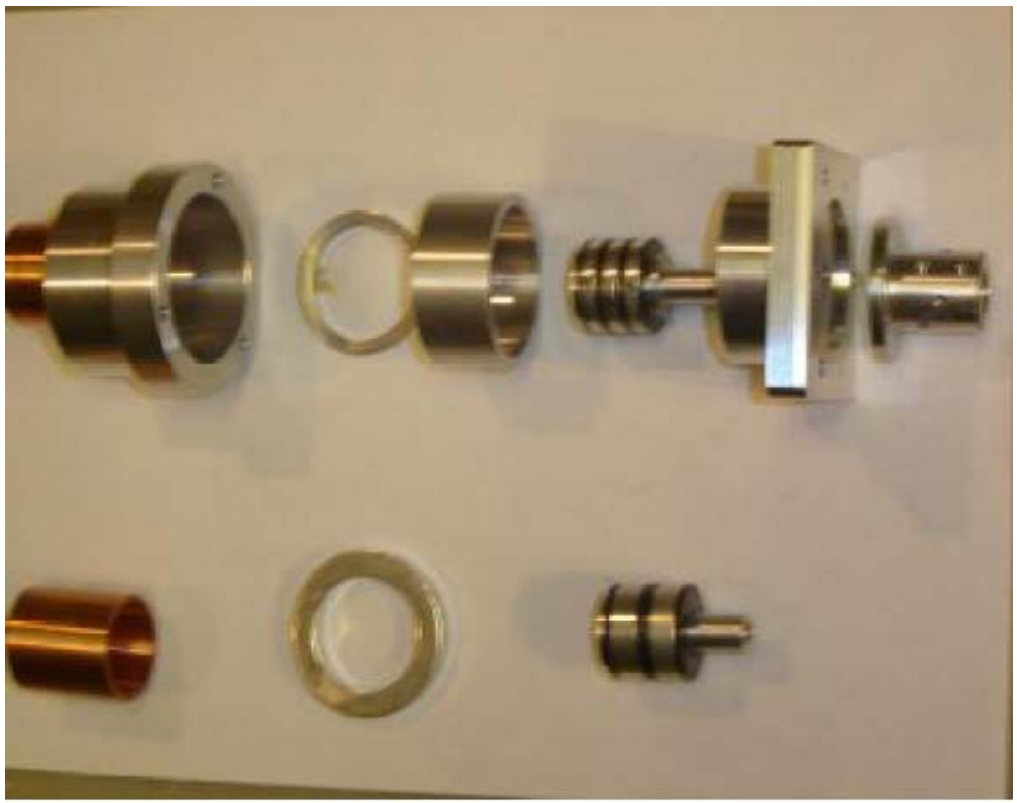


Fig. 8.15. Bearing parts. Above magnets and rings for a 3-row bearing. Below larger magnets for a 2-row bearing.

Material in rotor?;

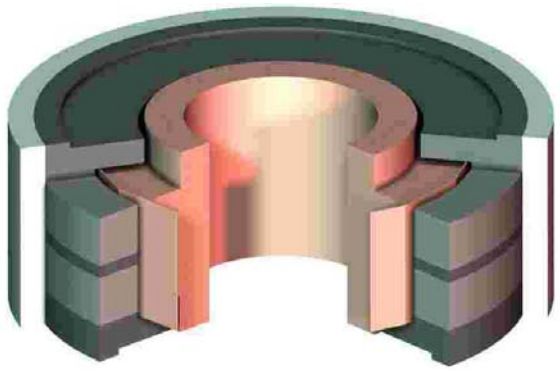
– Aluminum or copper

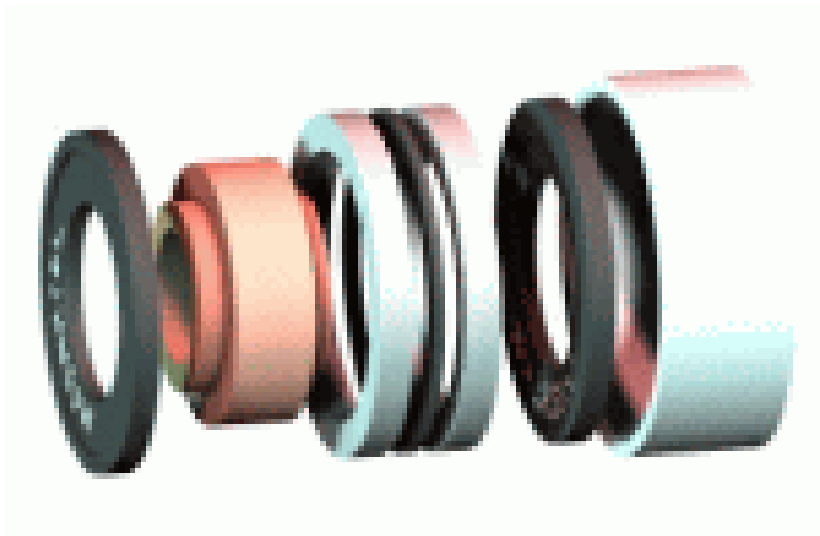
Additional benefits in vacuum applications with Magnetal solutions

Renewable Energy solutions such as
Thin film solar and Nuclear Fusion applications;

- **Thin Film Deposition**
  - Reduction in particles and impurities due to no lubrication requirement
  - Lower power consumption
  - No need for temperature control
  - Lower de-gassing => shorter evacuation time
- **Nuclear Fusion Applications**
  - No need for lubricants
  - No need for bearing control unit
  - No need for galvanic insulation between controller box and vacuum pump

Magnetal Bearings





Possible Application Areas

Magnetal passive magnetic bearing solutions offers base components to enable- and improve applications requiring and benefitting from high speed operation.

For more information

Visit our homepage:
www.magnetal.se

Or contact us at:
info@magnetal.se