Oil-Free, Bearingless Motors

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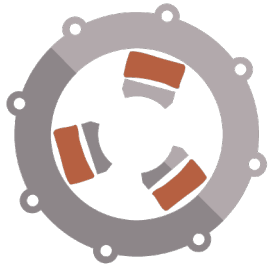


eLev Electric Machinery and Levitation Laboratory

MECHANICAL ENGINEERING

UNIVERSITY OF MINNESOTA

Problem: Bearings Limit Electrically-Driven Turbomachinery

Process Compatibility

Oil/Grease

Ball

Source: SKF

Journal

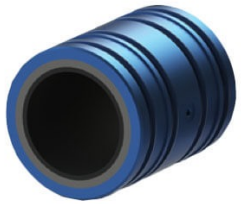
Source: Miba

Oil-Free

Gas Foil

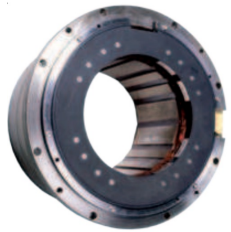
Source: Sulzer

Externally Pressurized



Source: Isotech

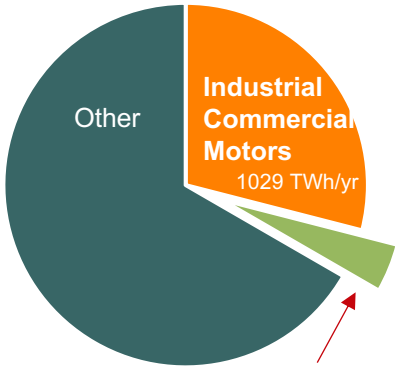
Magnetic



Source: S2M

Low Efficiency

US Electricity Consumption



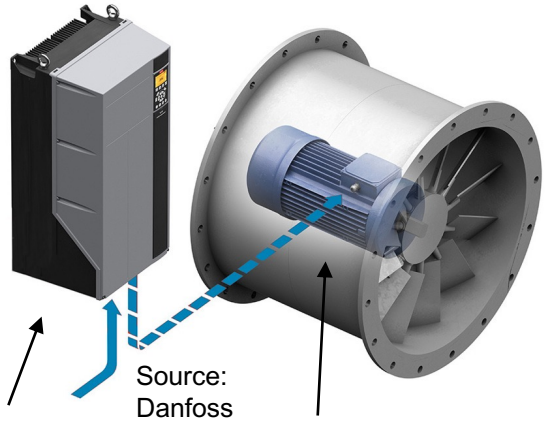
Variable Speed Drive (VSD) potential energy savings: 115 TWh/year

>11% of US electricity!

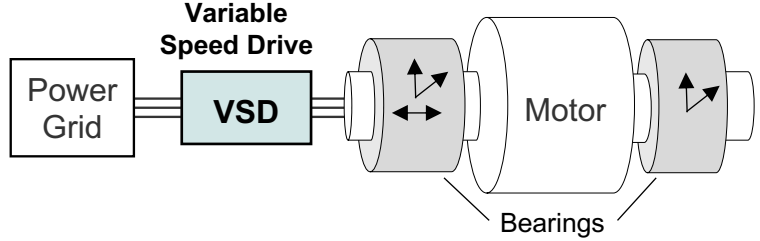
Per DOE: VSDs are cost effective in >75% of systems, but only adopted in 10%.

Why?

Limited Reliability



Source: Danfoss

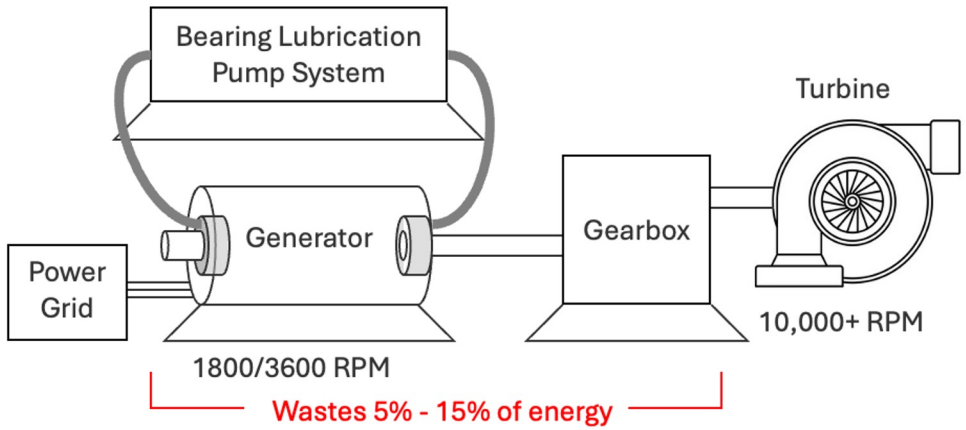


➔ VSDs increase motor failure rates by 3x
➔ 60% of motor failures due to bearings

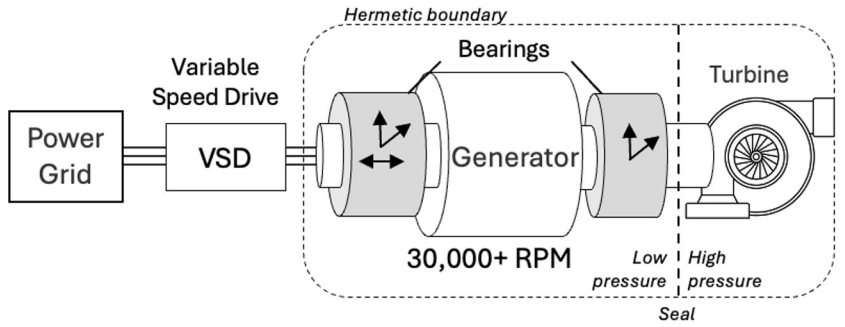
Problem: Closed Brayton Cycles Limited By Bearings

Need for cost-effective bearings that operate in hermetic environment

Conventional high power turbomachine system



Hermetic systems that are limited by bearing technology



- Large size → *compromises the power density advantages of fluids like sCO2*
- High cost → *dry gas seals*
- Maintenance, reliability concerns

- Compact and highly integrated
- Needs oil-free bearings
  - *Gas: foil or externally pressurized*
  - *Maglev*
- Current technology has shortcomings

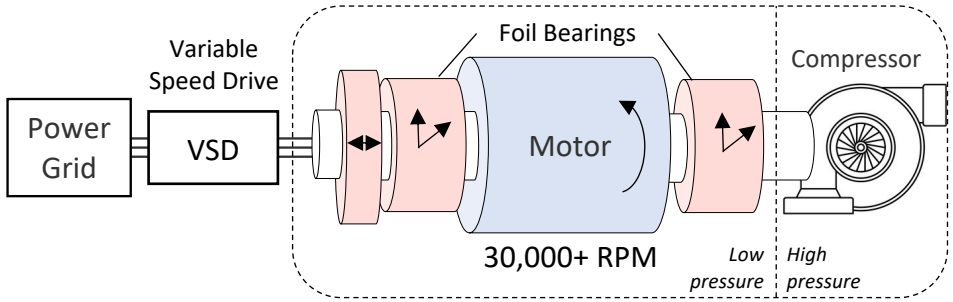
[1] T. Noguchi, W. Chan, N. Petersen, L Rapp, E L Severson, "Opportunities to Enhance sCO2 Power Cycle Turbomachinery with Bearingless Motor/Generators," *Solar Compass*, 2024.

Today's Hermetic Bearing Solutions

Gas Foil

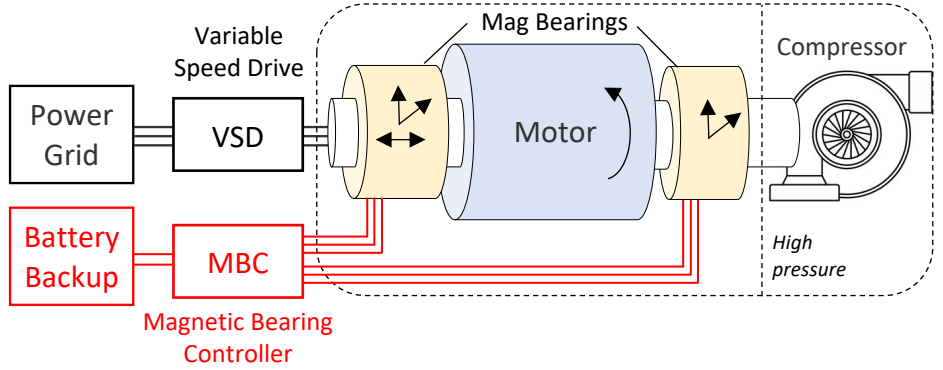
- **Benefits**
  - Completely passive operation
  - No pass-throughs into cavity
- **Challenges**
  - Wear during start/stop
    - Limits maximum shaft weight / lifetime
    - < 200 kW
  - Reputation for low damping

Source: Sulzer



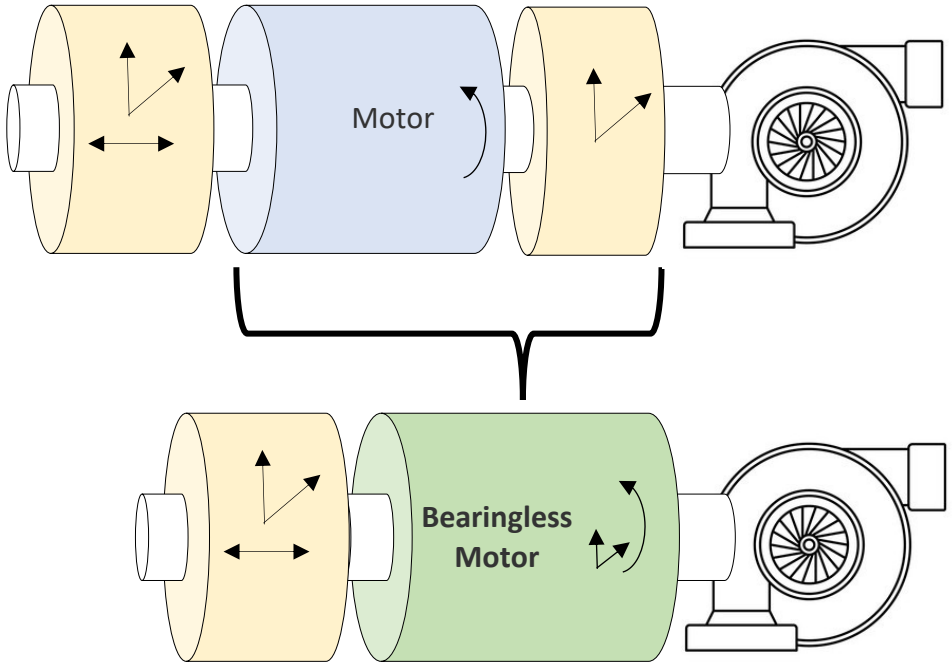
Active Magnetic

- **Benefits**
  - Works for large shafts
  - Excellent vibration / acoustics
  - System health monitoring
- **Challenges**
  - High cost
  - Increased axial shaft length
  - Large number of passthroughs



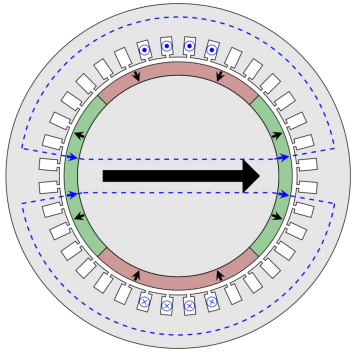
Our Solution: Bearingless Motors

Motor technology that controls magnetic forces on shaft



Maglev Motor
(2 AMB + 1 motor)

Bearingless Motor
(1 AMB + 1 motor)



Technology:

- Standard motor + new winding
- Standard VFD
- No performance degradation
- Support rotor weight with 5% power reduction

AMB: Active Magnetic Bearing

Status: Benchtop Demonstrations Complete

Bearingless PM Machines

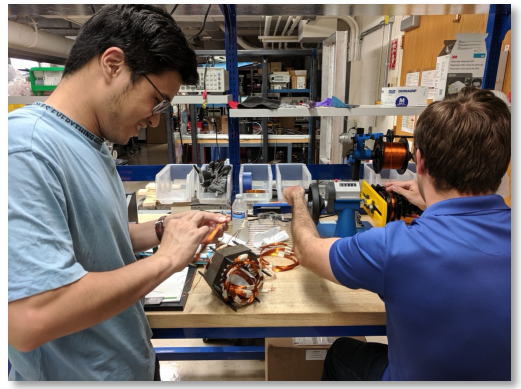
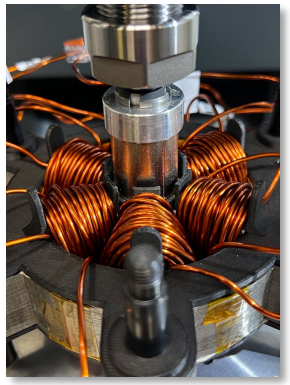
1. 1 kW, 30,000 r/min Motor
2. 10 kW, 160,000 r/min Motor
3. 3.4 kW, 35,000 r/min “Twin” Motor
4. 13 kW, 140,000 r/min “Twin” Motor
5. 50 kW, 80,000 r/min Generator
6. 13 kW, 160,000 r//min Motor + foil bearings

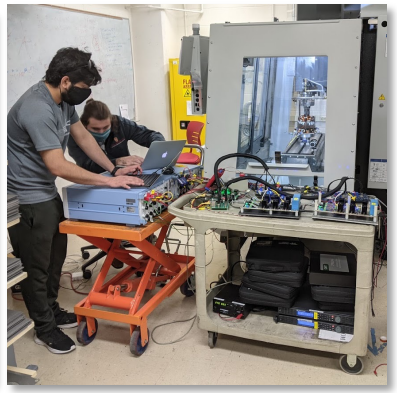
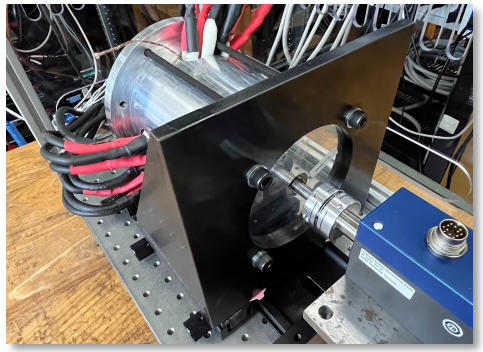
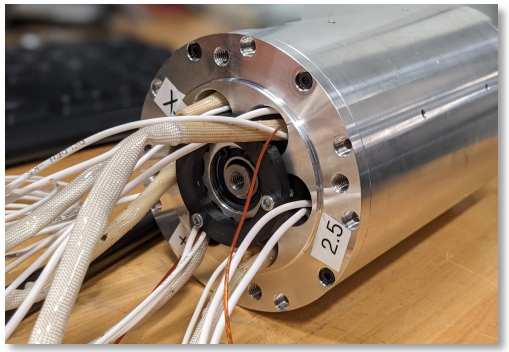
Bearingless Induction Machines

7. 3.6 kW, 30,000 r/min Motor

AC Homopolar Machines *(for flywheels)*

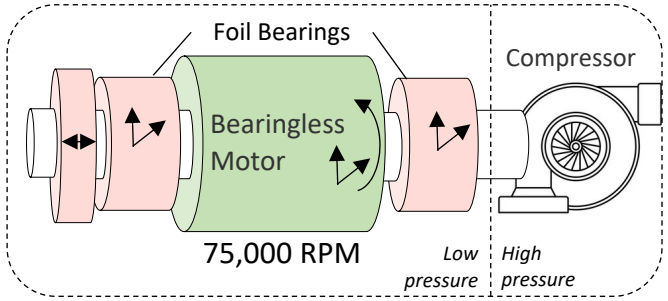
8. 1 kW, 3,600 r/min Motor
9. 6 kW, 10,000 r/min Motor/Generator

Status: Upcoming Application-Scale Demonstrations

Assisting Foil Bearings



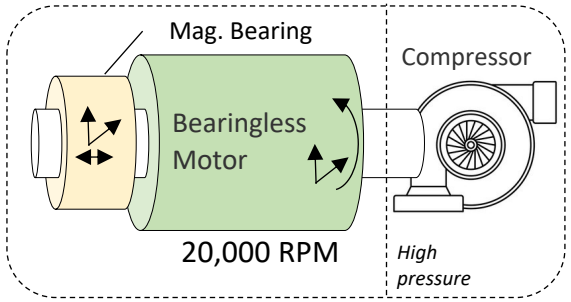
Create radial shaft forces to enable foil bearing use for large shafts

- Low cost
- Few components and passthroughs

Planned demonstration unit

- 100 kW
- 75 kRPM
- sCO2 turbomachine from Sandia Brayton Lab

Removing Magnetic Bearings



Use bearingless motor to eliminate a magnetic bearing actuator

- Largest shafts
- Best rotor dynamics

Planned demonstration unit

- 200 kW
- 20 kRPM
- Dyno testing planned for spring 2026

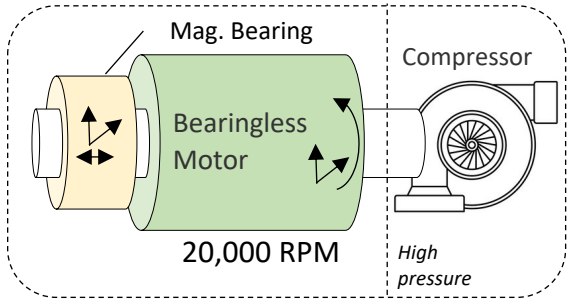
Sandia National Laboratories

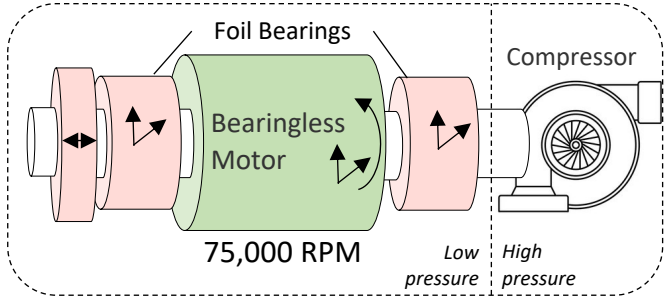
TRANE TECHNOLOGIES

NSF

Next Steps: Looking for Partners!

- Basic science figured out
- Focus on customization and demonstration
- Looking for collaborators
  - Application scale demonstrations
  - SBIR/STTR proposals
- Goal: commercialization





Interested in learning more? Contact us:

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