

# Design Implications of Rotordynamics and Mass Balancing on a 1.4 MW Partially Superconducting Machine

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# NASA's High Efficiency Megawatt Motor

- Enable **reduced energy consumption, emissions, and noise of commercial transport aircraft** via electrified aircraft propulsion
- NASA's High-Efficiency Megawatt Motor (HEMM) sized as generator for NASA's STARC-ABL concept



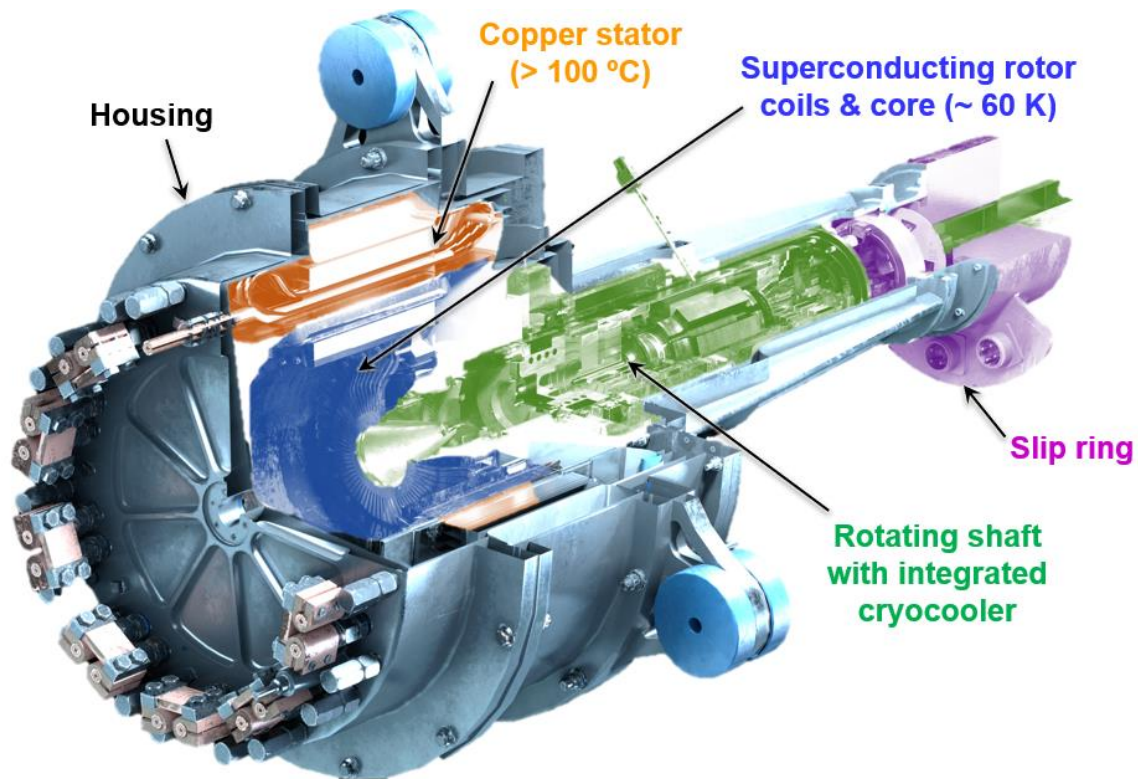
## Performance impact of HEMM

Refined assessment [1] (higher fidelity power system & thermal management)	Fuel burn with HEMM + advanced power electronics	Baseline
	-2.5% to -2.8%	Refined STARC-ABL rev. B2.0

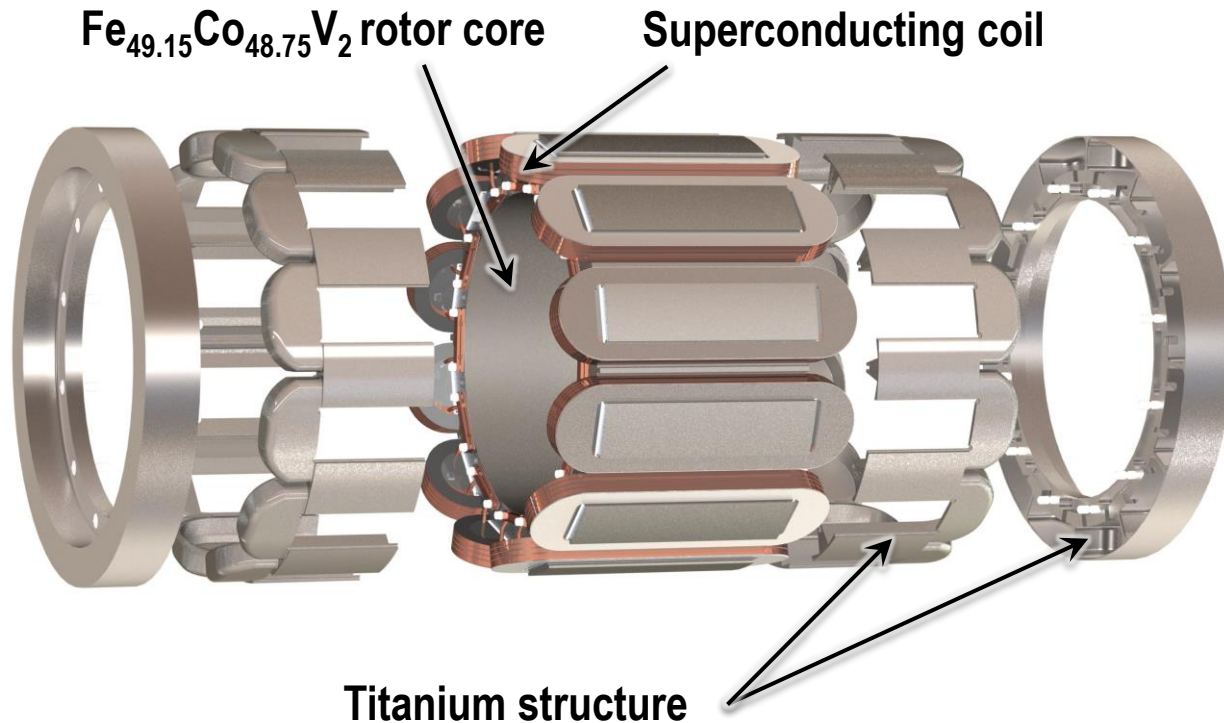
1. Schnulo, S.L. et al., Proc. of EATS, 2020.

# NASA's High Efficiency Megawatt Motor

Parameter	Value
Rated continuous power	1.42 MW
Nominal speed	6,800 rpm
Tip speed	107 m/s
Rated torque	2 kNm
Electromagnetic specific power goal	16 kW/kg
Efficiency goal	> 98%

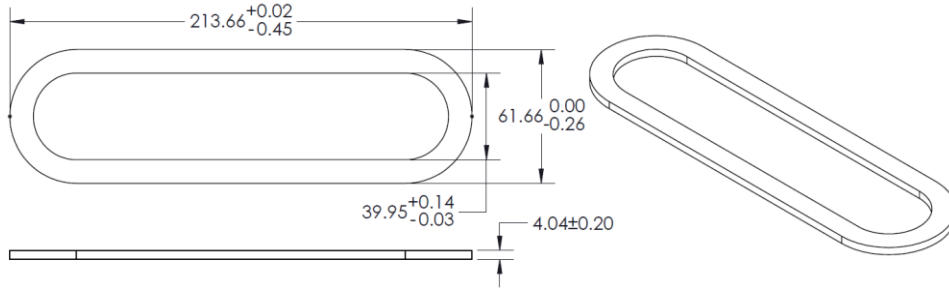


# Exploded View of the HEMM Rotor

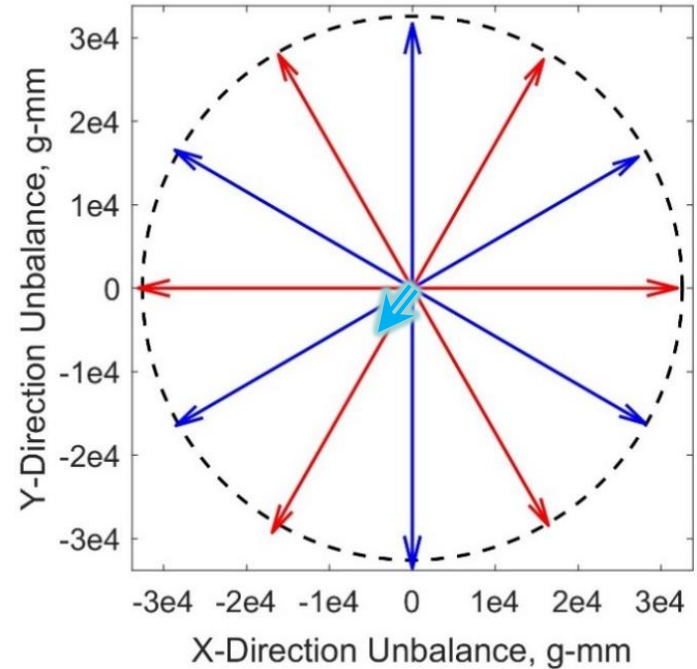


- Coil fabrication
  - 167 turns
  - Conductor thickness uncertainty
  - Winding fixture tolerance

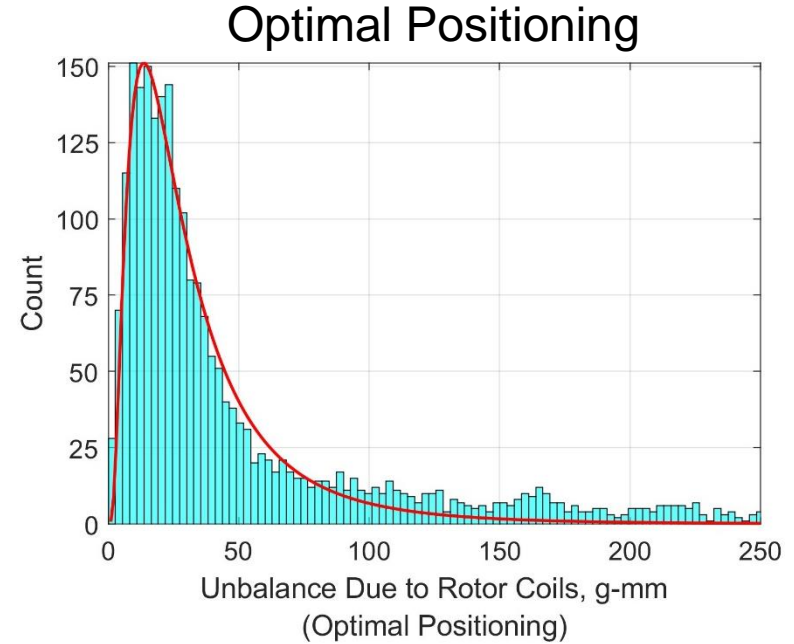
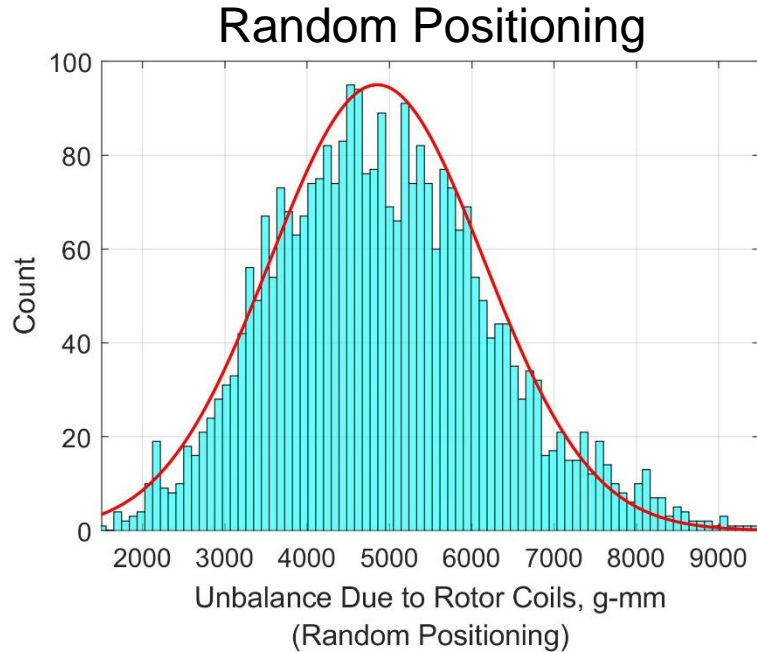
# Coil Unbalance



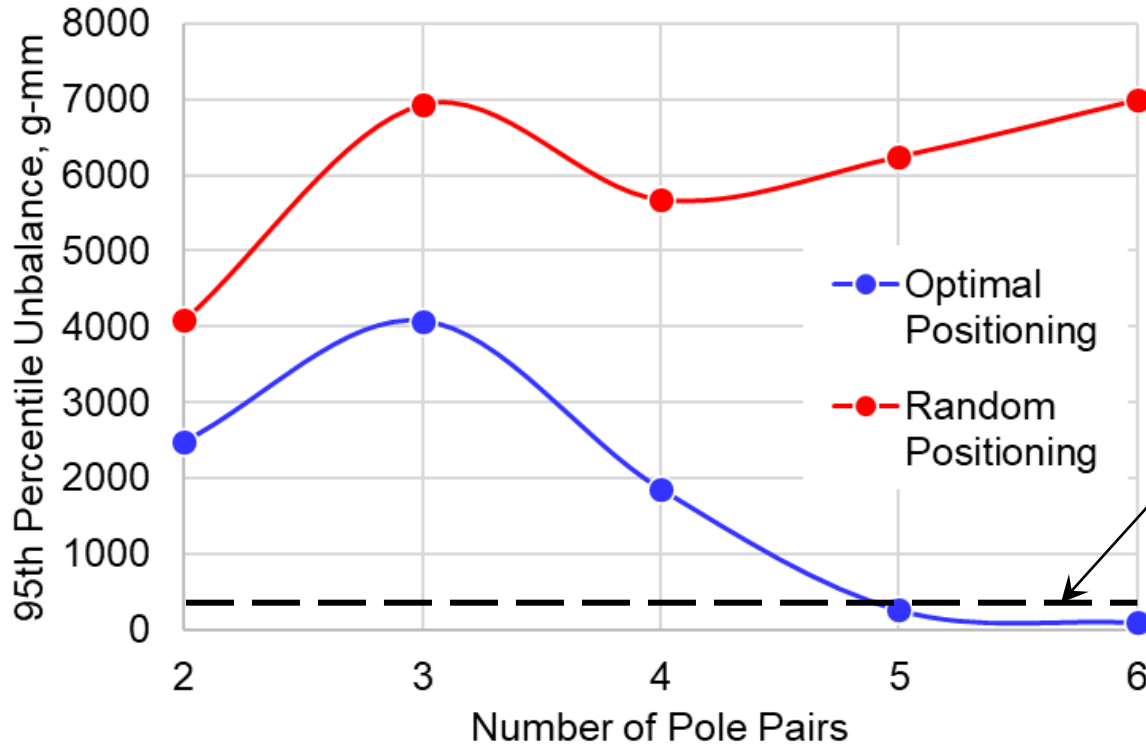
Coil Layer	Nominal Mass (average)	Standard Deviation
1 (largest radius)	233 g	5.3 g
2	181 g	6.8 g
3	181 g	6.8 g
4 (smallest radius)	202 g	4.5 g



# Coil Distribution Mass Unbalance



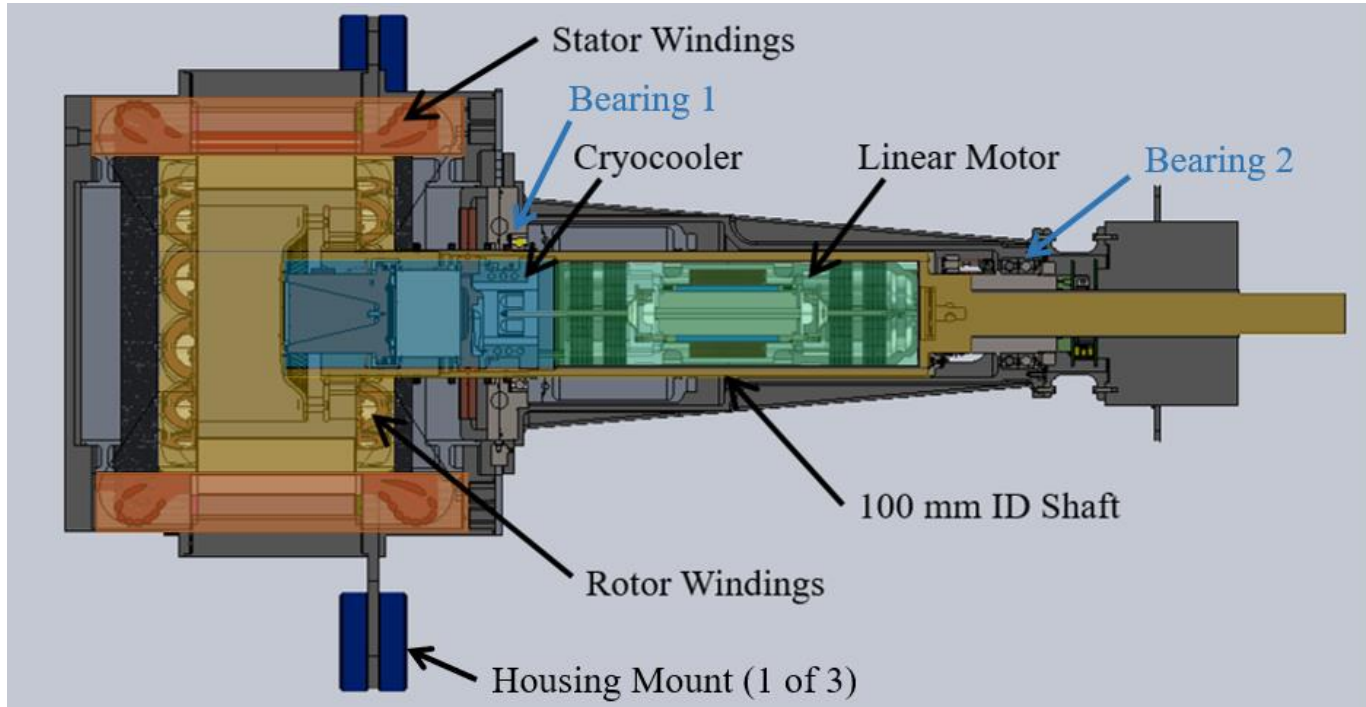
# Effect of Pole Pair Count



➤ 3 pole pairs is worst case for balancing through coil placement

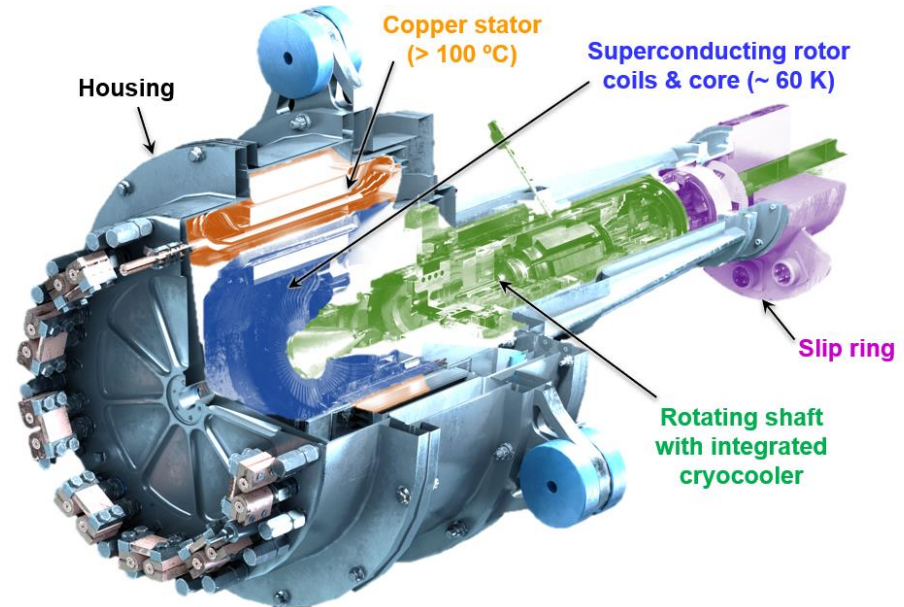
Target 305 g-mm for G2.5 balance for the HEMM

# The HEMM Geometry

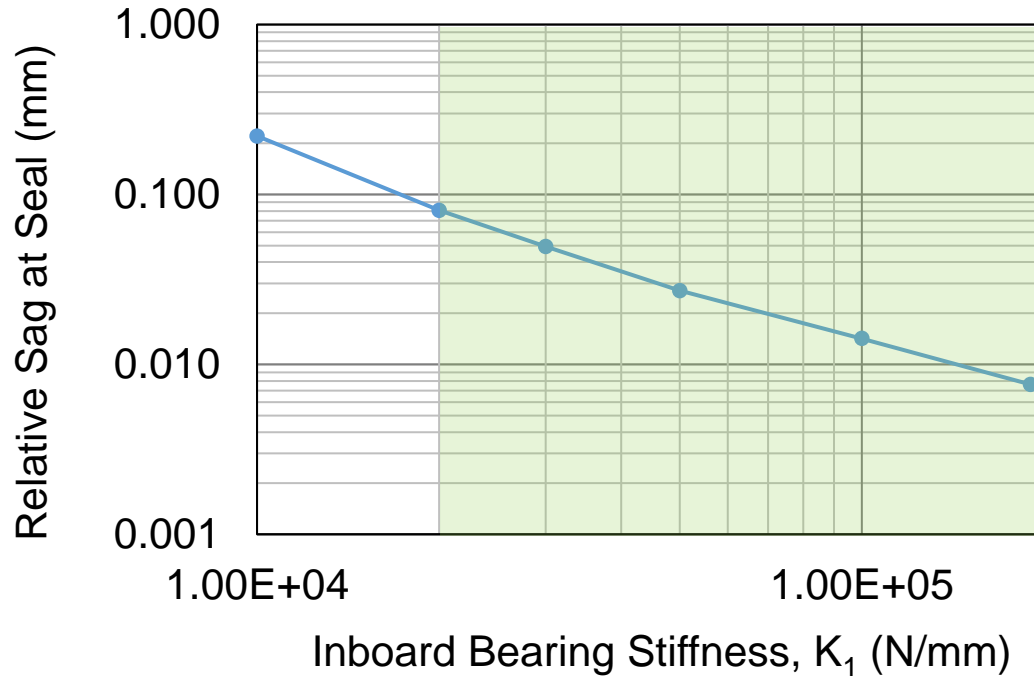


# Rotordynamic Requirements

Parameter	Value
Radial gap between rotor core and vacuum housing	1.0 mm
Vacuum seal allowable non-concentric position	0.25 mm
Vacuum seal allowable radial eccentricity at max speed	0.23 mm



# Static Sag due to Gravity

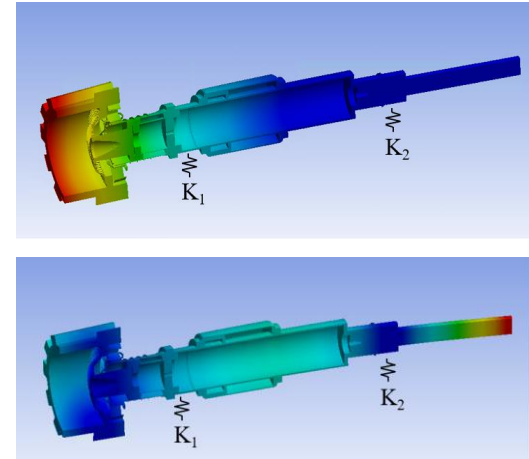
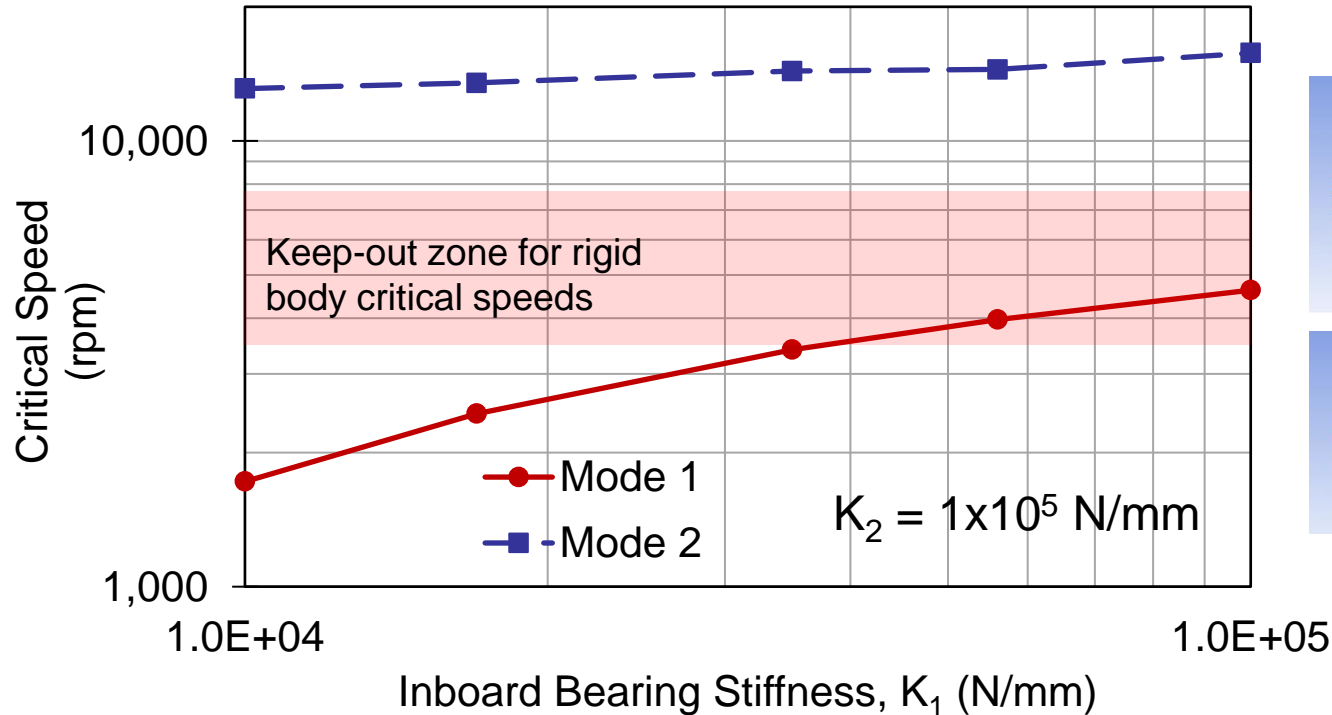


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Vacuum seal allowable non-concentric position	0.25 mm
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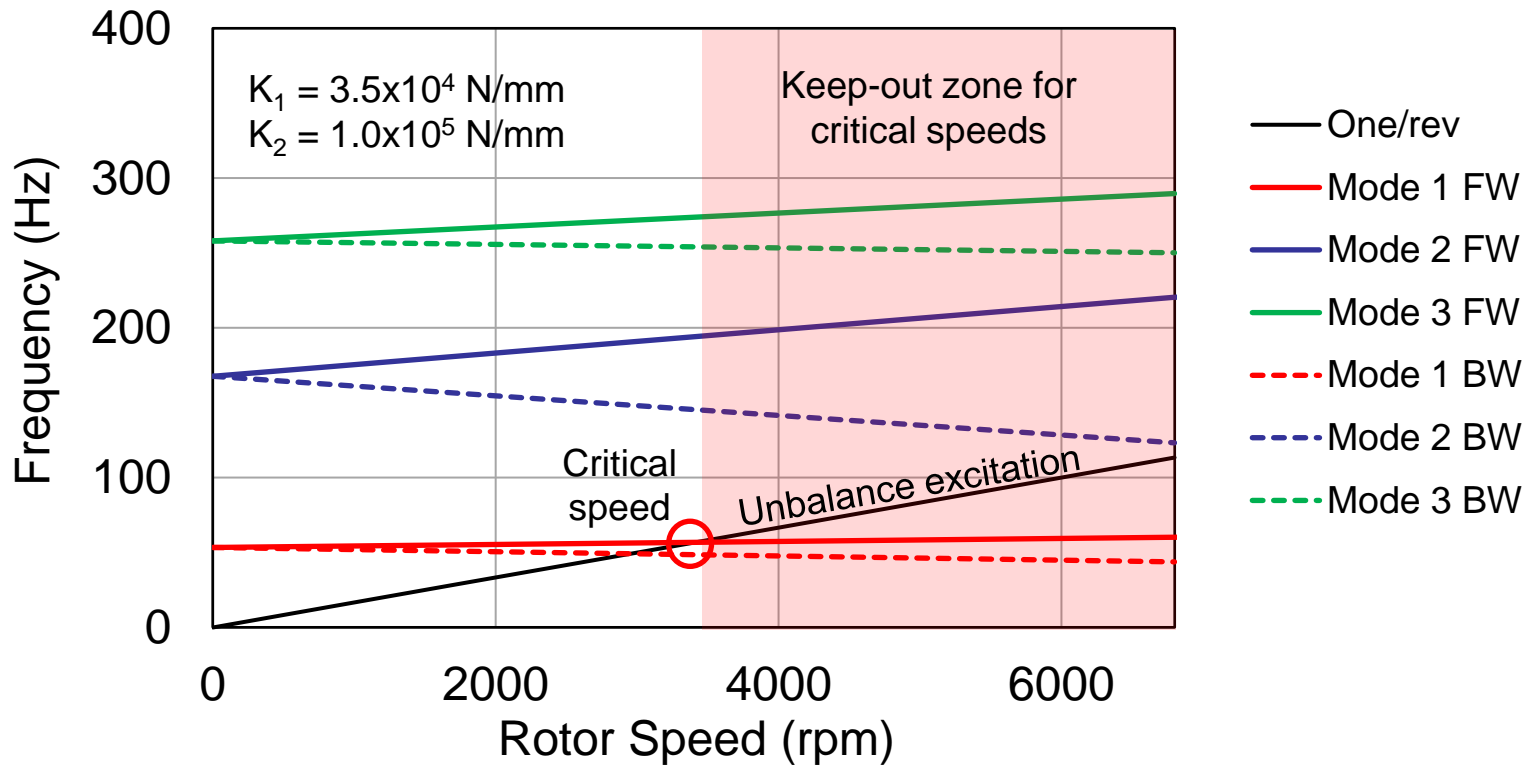
# Rotordynamic Requirements

Parameter	Value
Operating Speed	6,800 rpm
Idle Speed (assumed 60% of operating speed)	4,080 rpm
Maximum operating speed (assumed 105%)	7,140 rpm
Rigid body mode critical speeds (15% margin to operating speed range)	< 3,468 rpm or > 7,820 rpm
Bending mode critical speeds (20% above maximum operating speed)	> 8,211 rpm

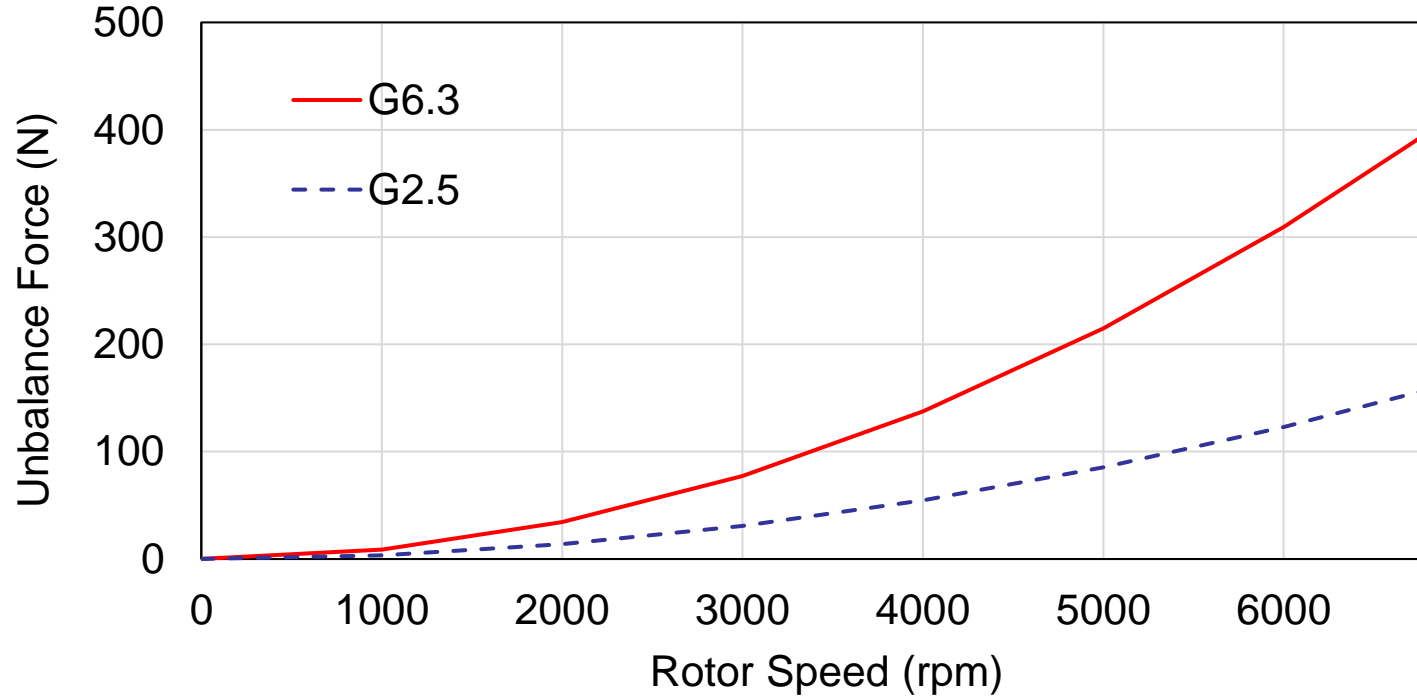
# Critical Speed Map



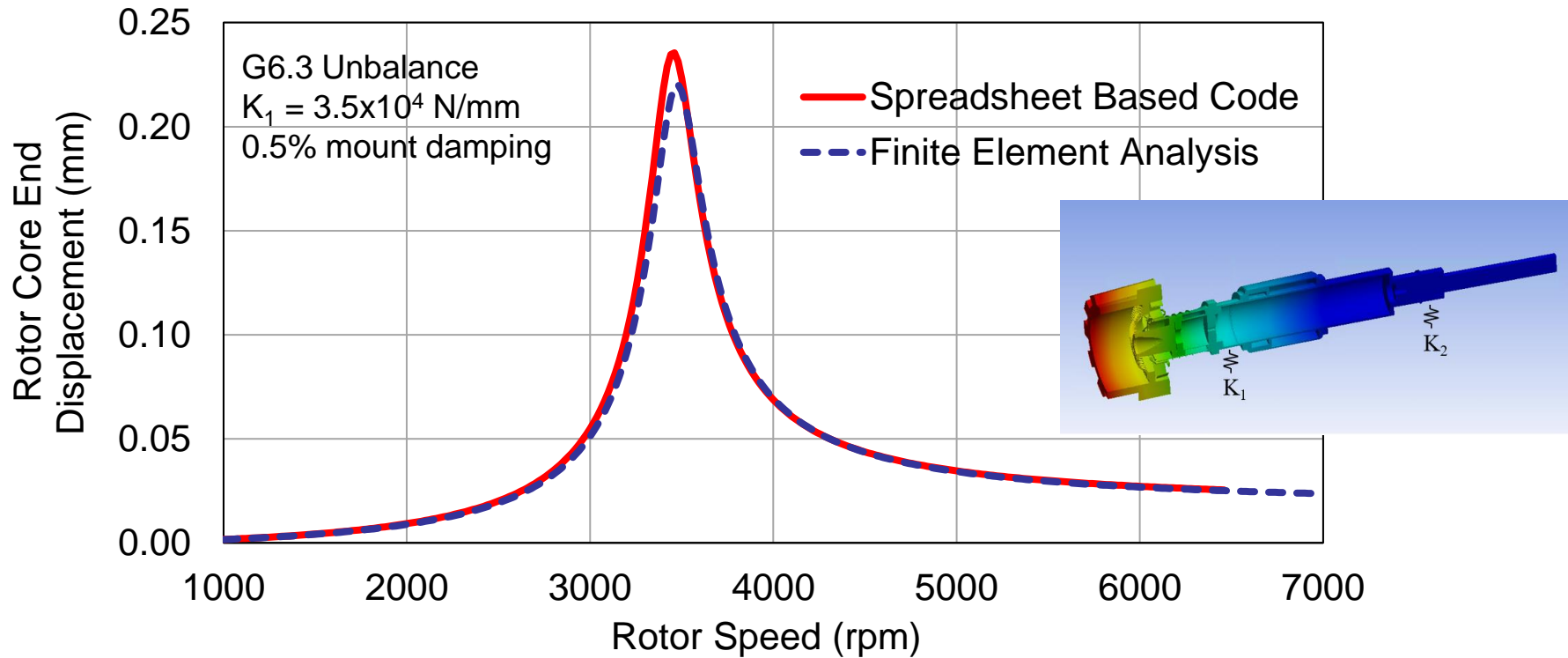
# Campbell Diagram



# Unbalance Force



# Radial Response to Unbalance



# Compliant Mount at Inboard Bearing

- Rotordynamics:
  - Inboard bearing mount stiffness and damping is key to meeting rotordynamics requirements
  - To prevent static sag, target  $>2.0 \times 10^4$  N/mm
  - To keep first critical speed low, target  $< 3.5 \times 10^4$  N/mm
- Options:
  - Squeeze film damper with centering spring
  - Elastomeric damper
  - Metal mesh damper

# Discussion

- Coil distribution:
  - Number of pole pairs affects ability to meet balance specification through coil placement
  - Mass balancing also balances the rotor's magnetomotive force
- The HEMM motor design:
  - Overhung rotor adds complexity to the rotordynamics design
  - Lessons learned from this design will drive improvements for the next iteration

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