Seamless Electric to Hydraulic Conversion

Presenters:

James Van de Ven, Associate Professor,
University of Minnesota

Eric Severson, Assistant Professor,
University of Wisconsin - Madison

Team:

James Van de Ven, Univ of Minnesota
Jenny Swanson, UMN
Eric Severson, UW - Madison
Anvar Khamitov, UW-Madison

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Barrier: Electric → Hydraulic Conversion

- Electric to Hydraulic Conversion Critical:
  - Electrification of Mobile & Industrial Systems
  - Many Intermittent Hydraulic Loads
- Applications:
  - Electro-Hydraulic Actuation (EHA)
  - Charge Pump in HST
  - Hydraulic Steering
  - Intermittent Hydraulic Drives
  - Robotics
  - Emerging: Zero Emission Vehicles, Fuel Cells

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- EHA Benefits:
  - Efficient (Valveless)
  - Precise Control
  - Leak Resistant
  - Regeneration

State of the Art

- Modular components
  - Bulky
  - Redundant
  - Additional energy losses
- Poor cooling of electric machine
- Current/pressure ripple at low speeds

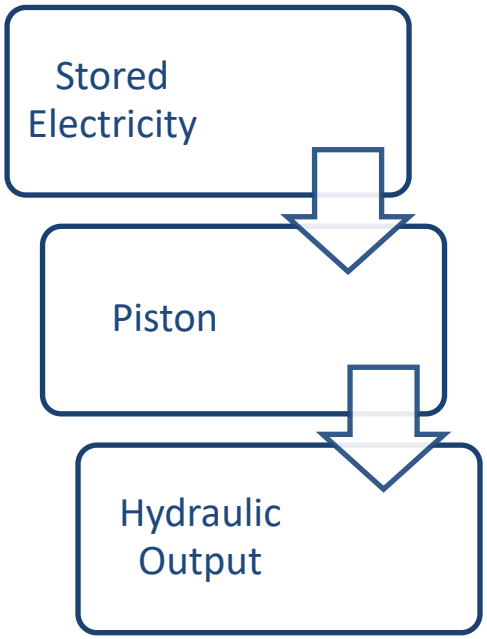
Concentric hydraulic power unit

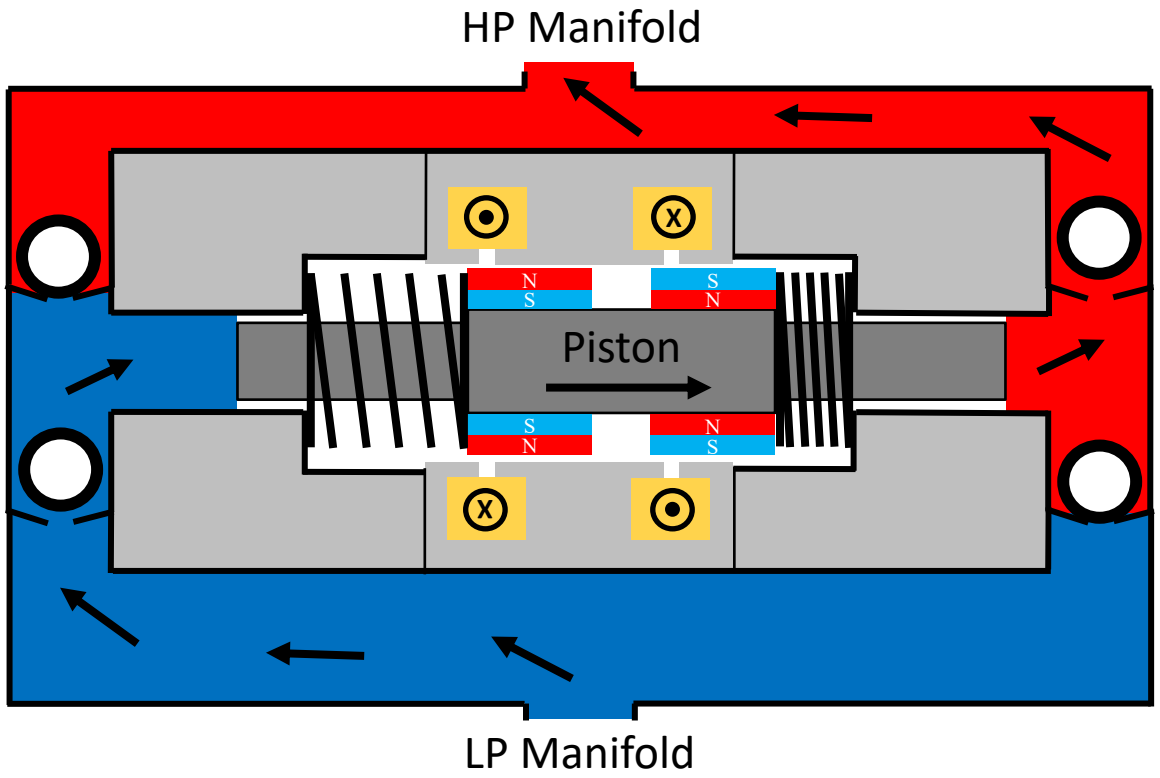
State of the Art

- Stored Electricity
- Rotating Mechanical
- Pump Mechanism
- Piston
- Hydraulic Output

Concentric hydraulic power unit

Linear Electromagnetic Piston Pump

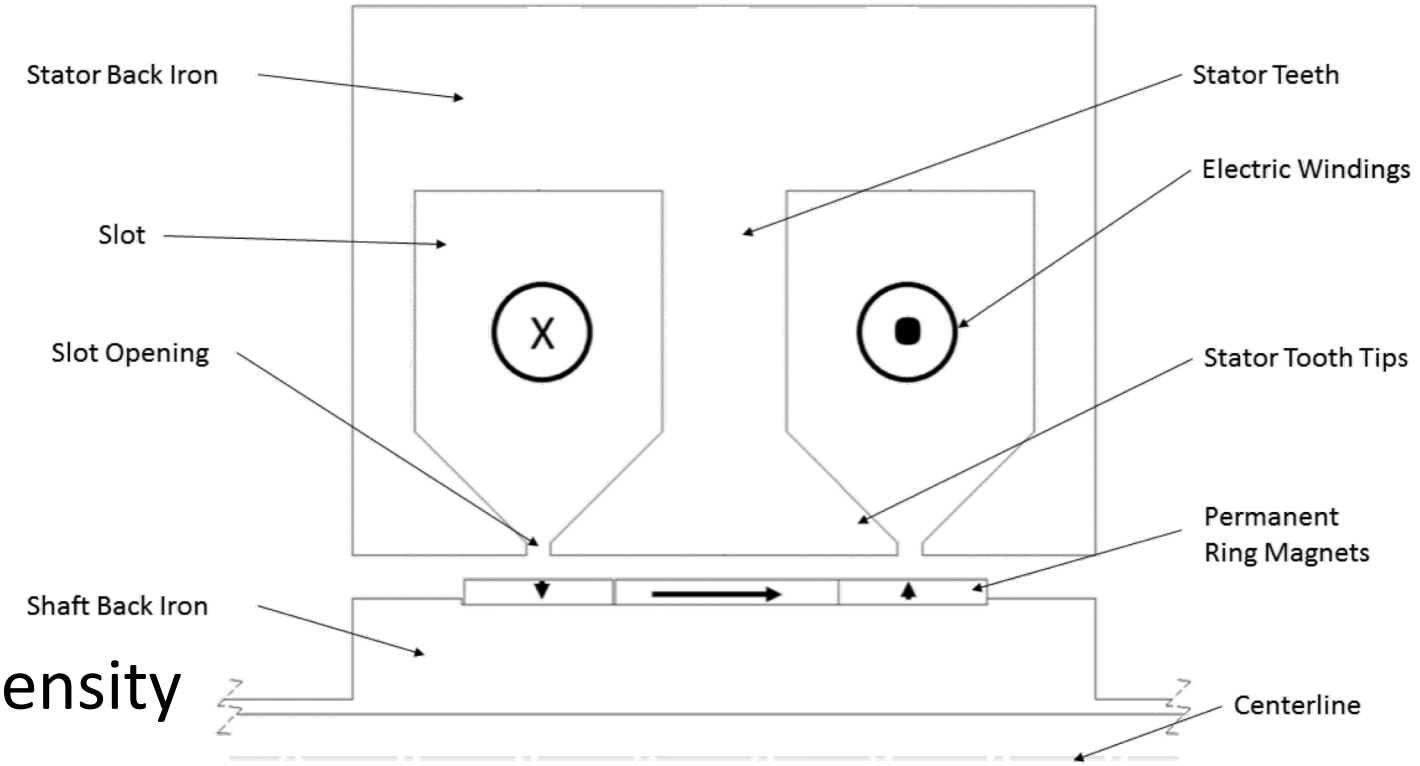




Our Approach: Seamless Integration

- Hydraulic Cooling of Electric Motor & Drive
  - Increased power density
- Tight Integration
  - Fewer (moving) components
  - Reduced weight and volume
  - Fewer energy conversions
  - Improved control bandwidth
- Wide Band Gap MOSFETS
  - Faster switching frequency
  - Higher efficiency
  - Higher power density

Tubular Moving Magnet Linear Motor

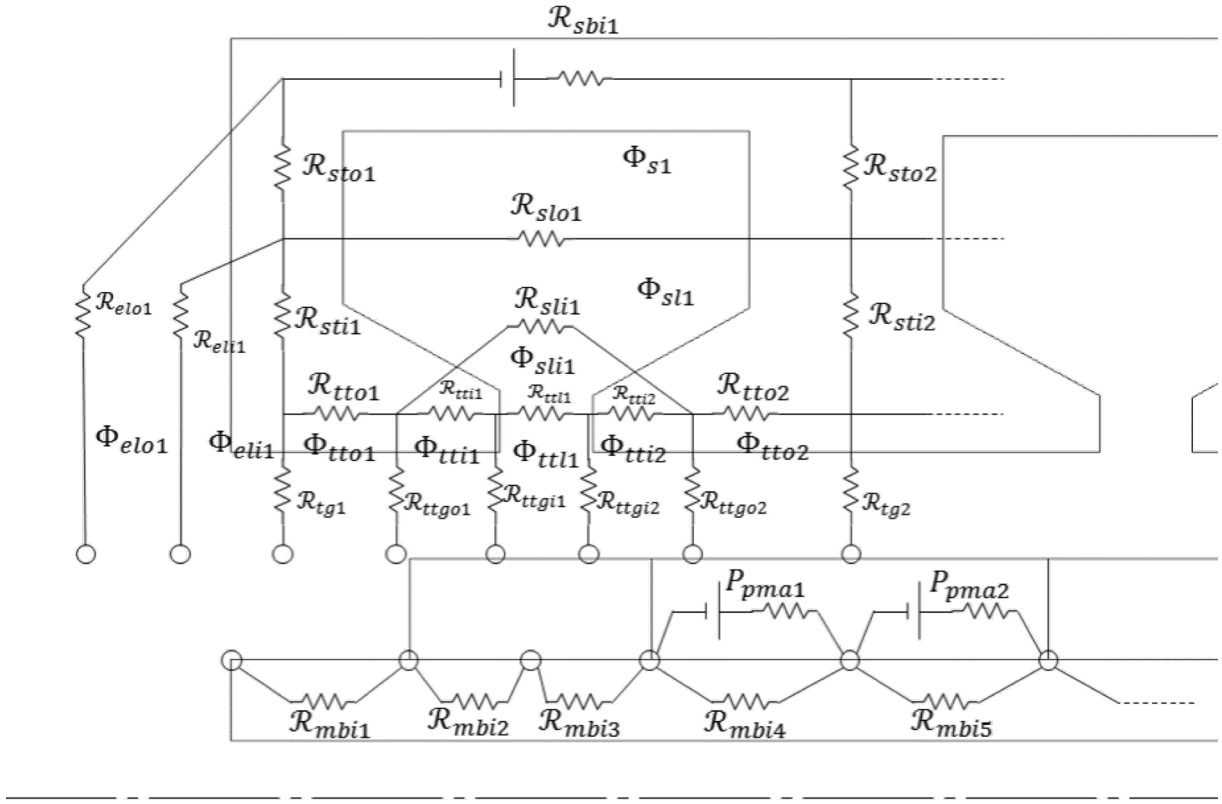


Benefits:

- High force density
- Low inductance
- Simple construction
- Simple electrical supply

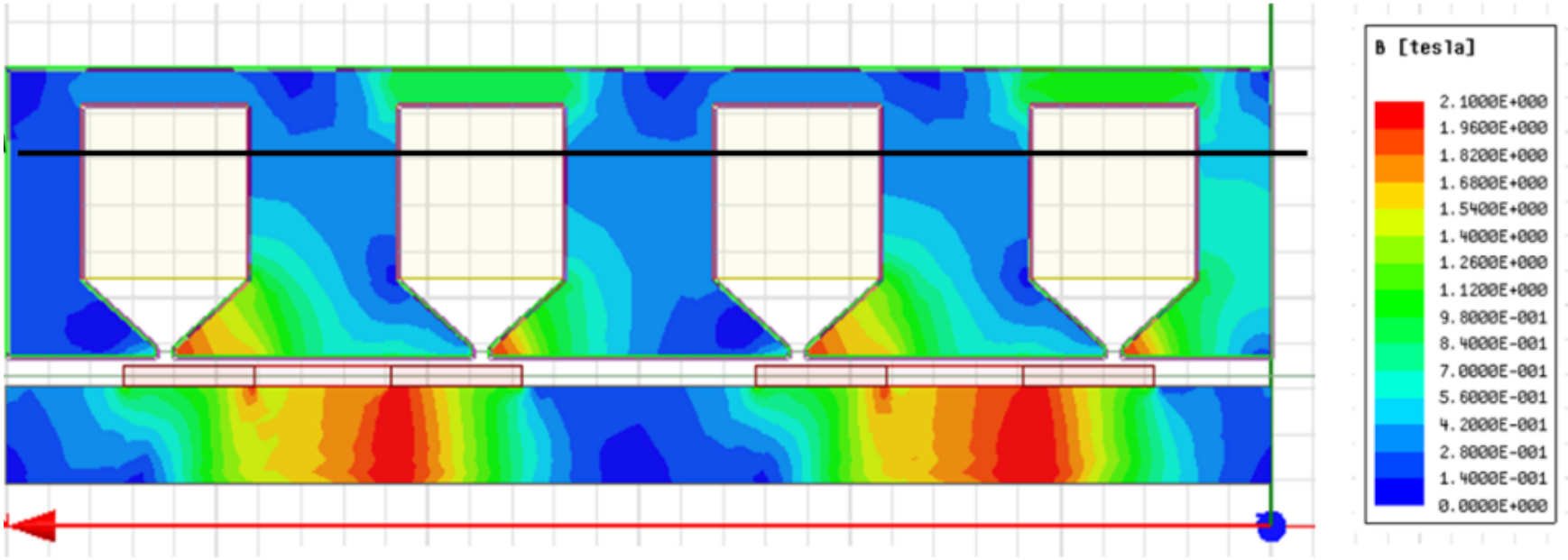
Prior Research:

Magnetic Equivalent Circuit (MEC) Model:



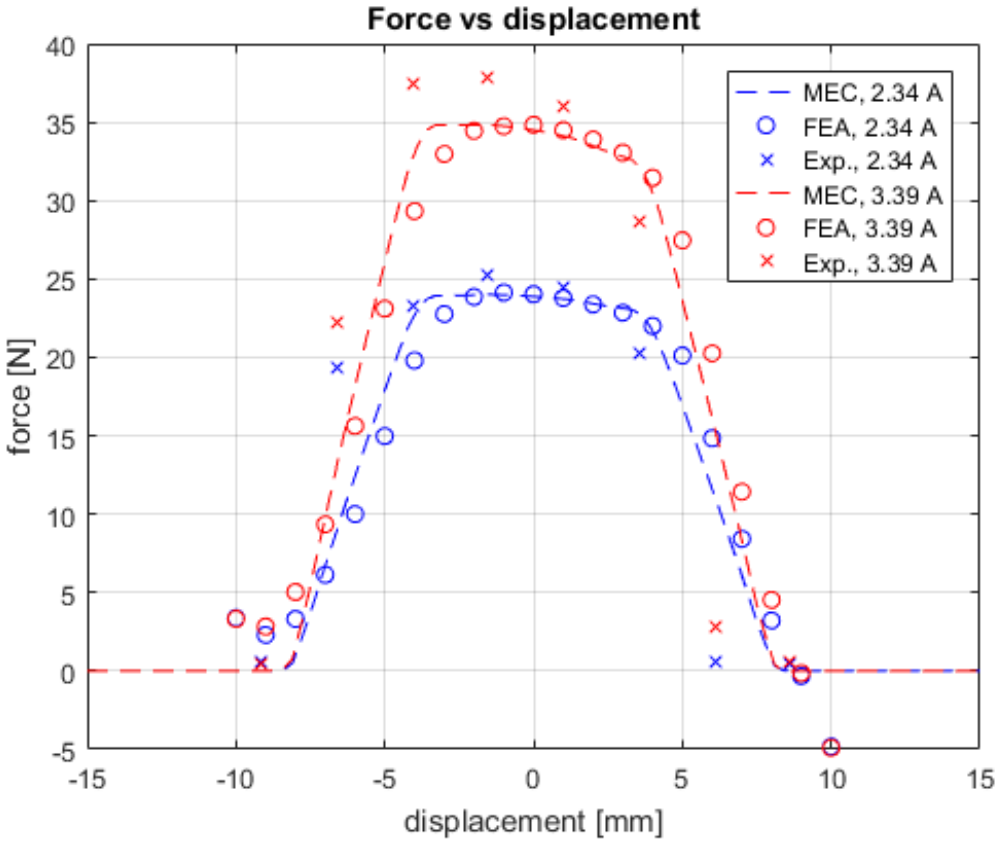
Prior Research:

FEA Model of Static Electro-Magnetics



Prior Research

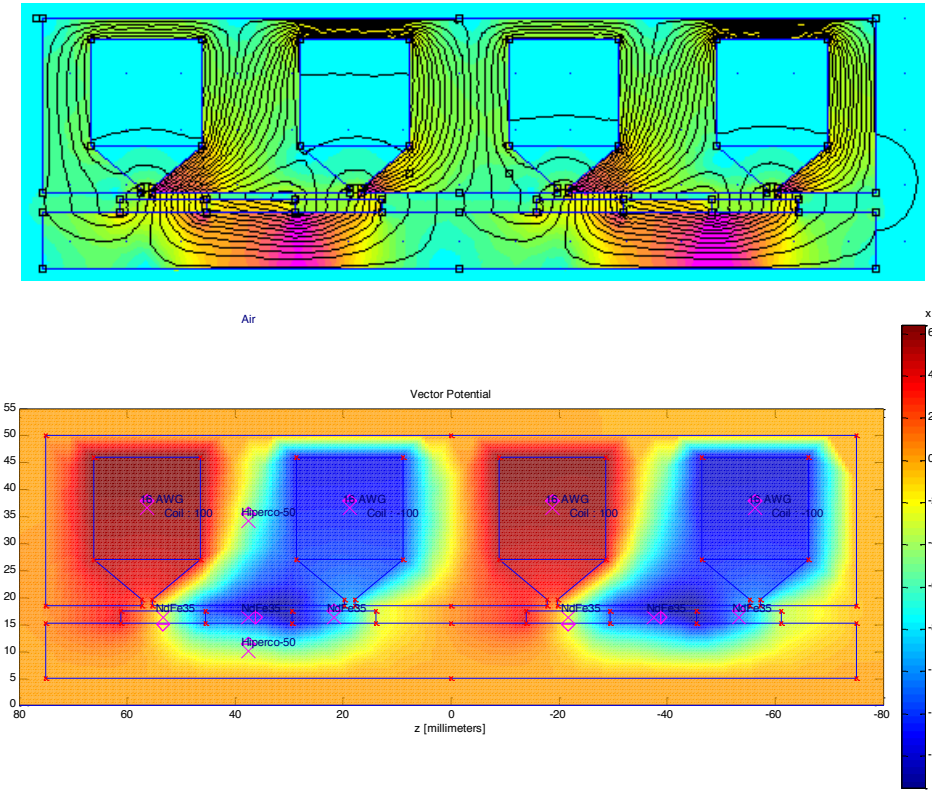
- Good static model agreement
- Optimized solutions violated MEC assumptions
- Dynamic performance disagreement



New Modeling Approach

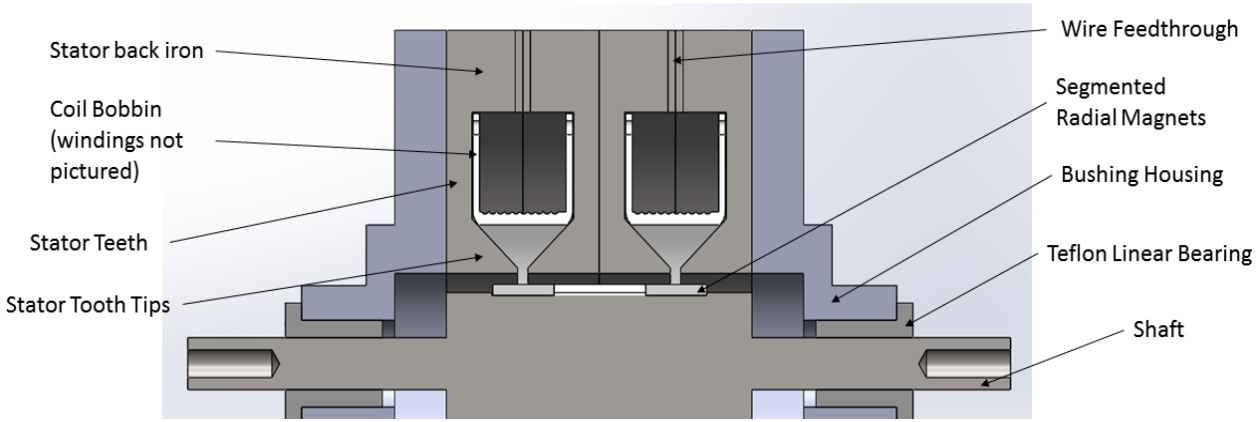
- Replace MEC with opensource FEA
  - FEMM and XFEMM
  - Unlimited parallel solves
- Develop Matlab scripts
  - interface mechanical and electrical domains

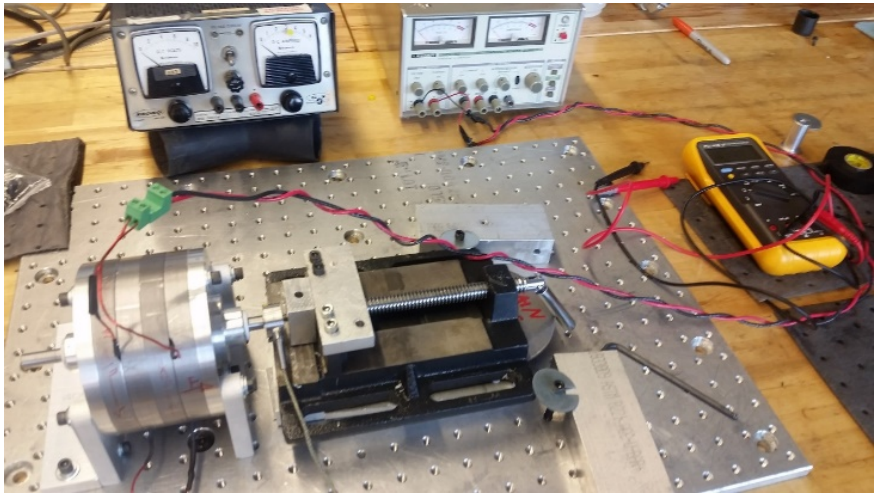
Finite Element Method Magnetics (FEMM)



Prior Research

Experimental Validation





Research Map

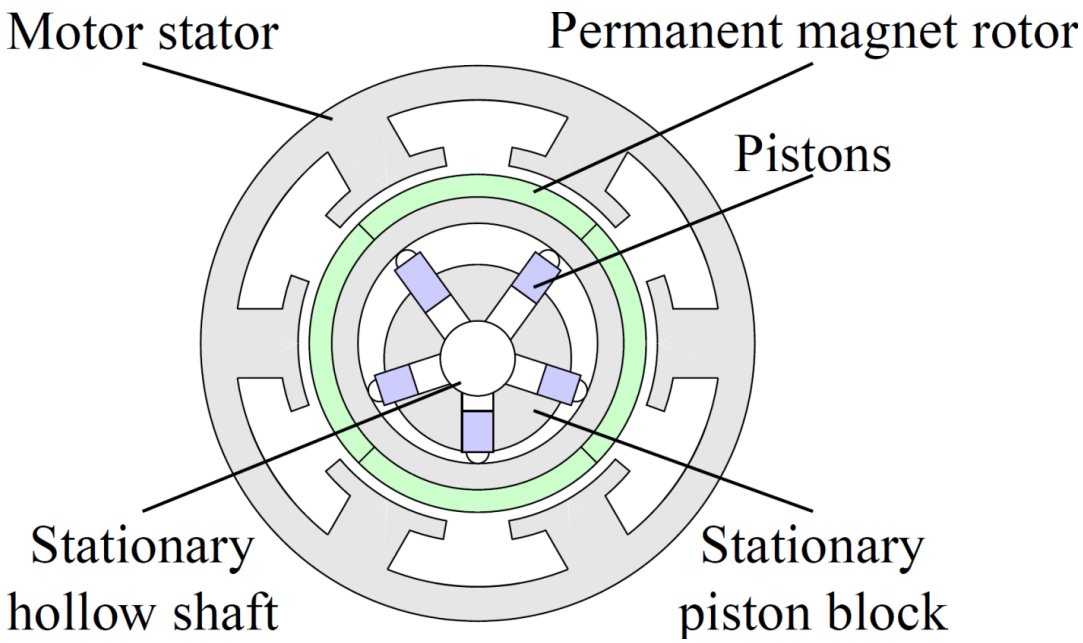
Year 1: Model development and prototype design

- Task 1: Define the design requirements
- Task 2: Construct first-order models
- Task 3: Increase model detail to inform design
- Task 4: Select prototype parameters and detailed design

Year 2: Laboratory benchtop prototype

- Task 5: Fabricate prototype machine
- Task 6: Experimental testing
- Task 7: Hardware-in-the-loop testing

Parallel Project: Rotary Machine



DOE Sponsored Project:

- Integrate pump as rotor of electric motor

Wrap-up

- Emerging Needs for Electric → Hydraulic Conversion
- Tight Coupling Improves Power Density & Efficiency
- Approach: Linear Electromagnetic Piston Pump

- Industry Request: "Drive cycle" data for charge circuits in various applications

- Contact: vandeven@umn.edu, eric.severson@wisc.edu