Application of High Performance Research Computing to Parametric Design of Magnetic Gears Using a Genetic Algorithm

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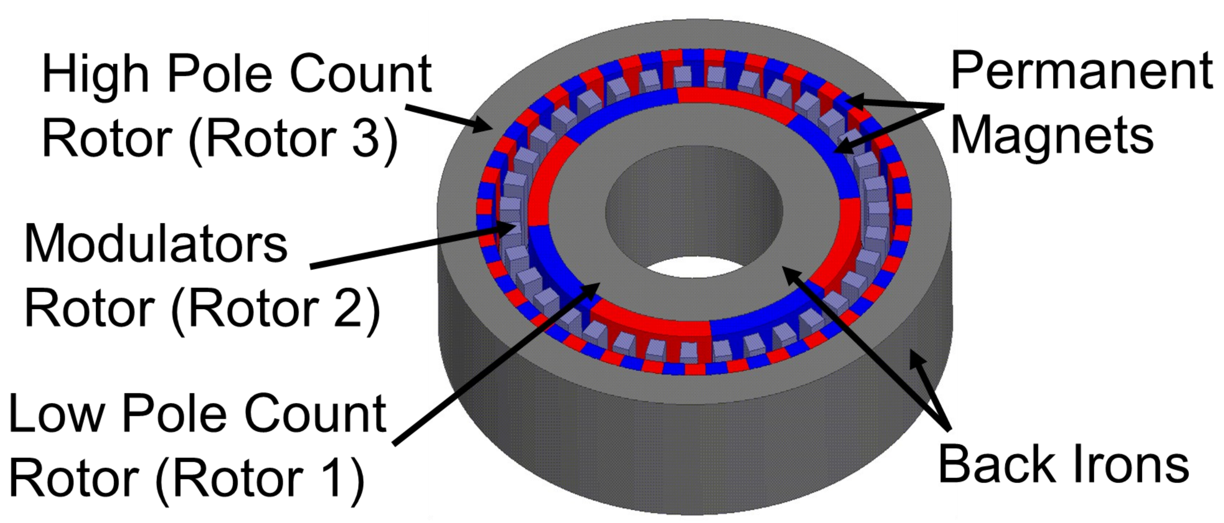
BACKGROUND

- Use ANSYS Maxwell for finite element analysis (FEA) simulations of electromagnetic devices.
  - Motors and Generators
  - Magnetic couplings and magnetic gears
- Evaluate, torques, forces, magnetic fields, and losses.

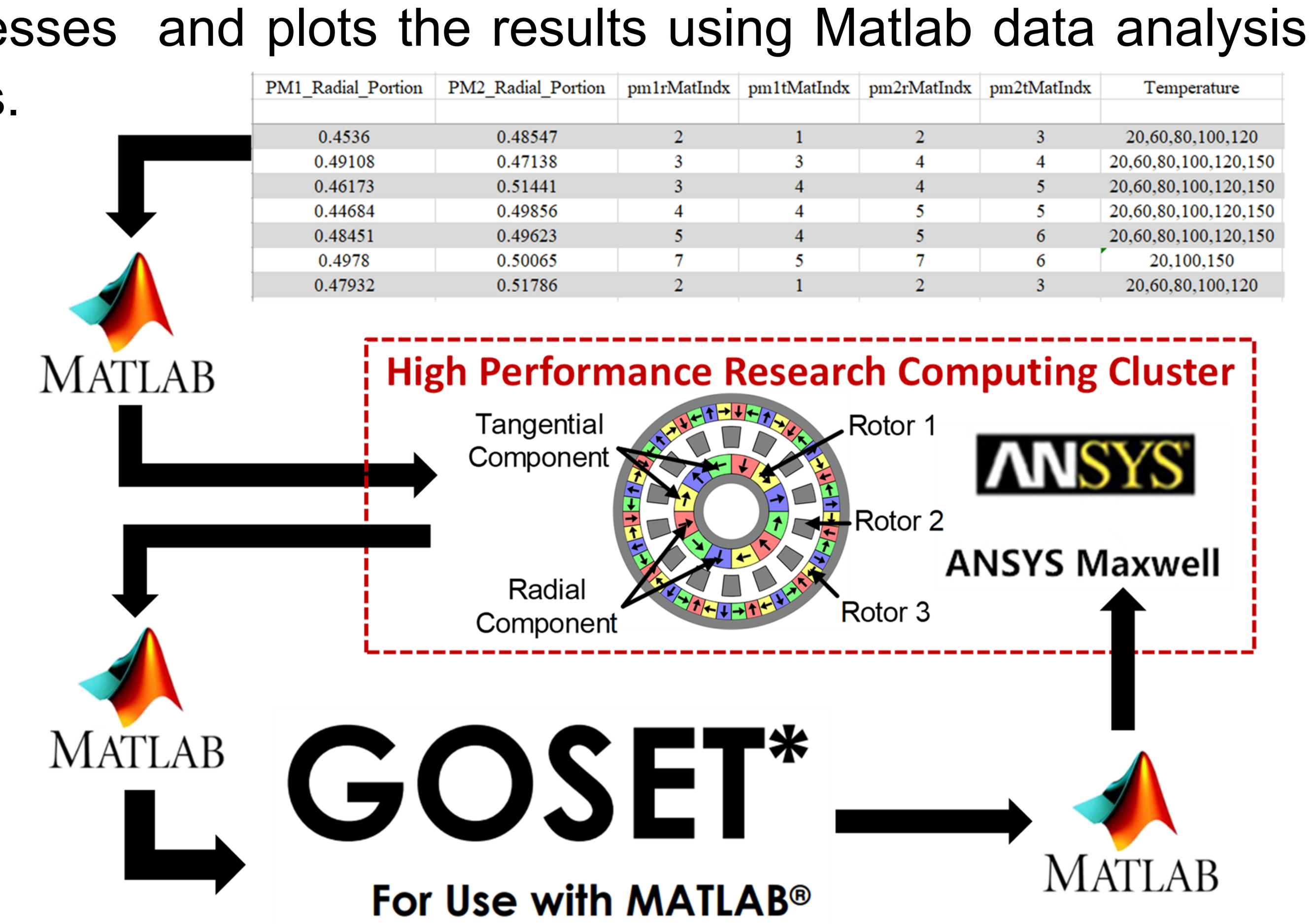


Magnetic Gear 3D Model

- Extensive simulations required for a thorough characterization of design and performance trends.
- Magnetic gears have significant end effects which require computationally intensive high resolution 3D models to accurately assess.
- Use open source GOSET genetic algorithm optimization tool for Matlab.
- Use High Performance Research Computing (HPRC) Linux clusters for the parallel simulation of numerous cases.
  - Use HPRC's resources to perform 36 multi-objective optimizations at 6 different permanent magnet temperatures.

WORKFLOW

- On a local workstation, the user:
  - Creates a parameterized model template in ANSYS Maxwell.
  - Enters the desired initial population simulation parameter values and ranges in a spreadsheet in Excel.
- On a local workstation, a Matlab script:
  - Copies and modifies the template to create ANSYS Maxwell files for the individuals of that generation.
  - Uses scp to move the simulation files to a directory on the Linux cluster.
  - Creates simulation job (.slurm and .LSF) files which include instructions for the Linux cluster to solve the ANSYS Maxwell files and export the relevant data into .csv files.
- On the Linux cluster, a bash script:
  - Submits simulation job (.slurm and .LSF) files for corresponding Maxwell files.
- On a local workstation, a Matlab script:
  - Automatically periodically polls the cluster to download any new .csv files.
  - Calculates fitness of designs.
  - Passes the calculated fitness and parameters of the designs through the open source GOSET genetic algorithm, which creates the next parameters for the next generation of designs.
  - Automatically repeats this process for each generation.
- On a local workstation, the user:
  - Post-processes and plots the results using Matlab data analysis and visualization scripts.



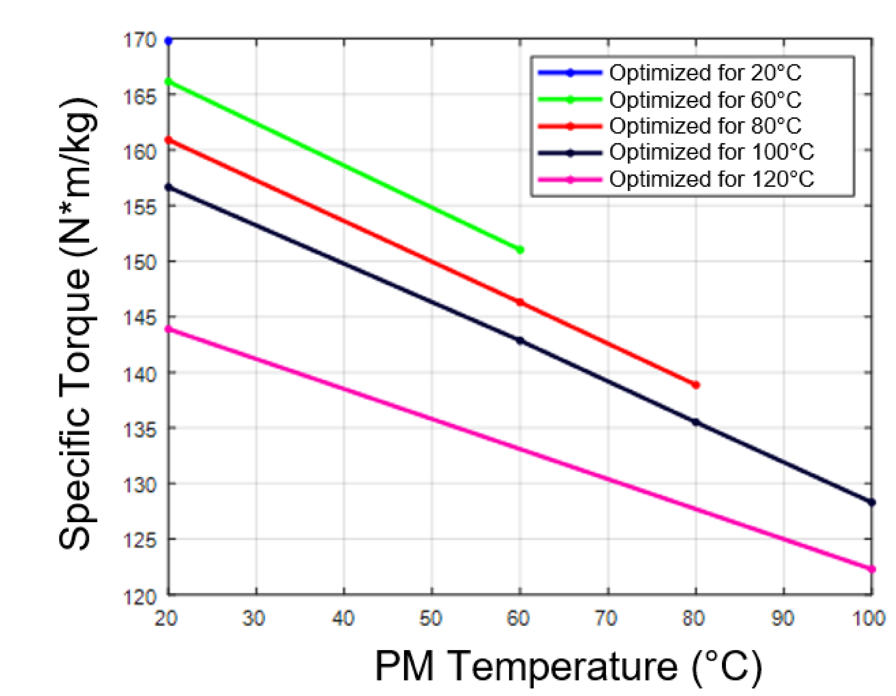
PM1_Radial_Portion	PM2_Radial_Portion	pm1rMatIndx	pm1tMatIndx	pm2rMatIndx	pm2tMatIndx	Temperature
0.4536	0.48547	2	1	2	3	20,60,80,100,120
0.49108	0.47138	3	3	4	4	20,60,80,100,120,150
0.46173	0.51441	3	4	4	5	20,60,80,100,120,150
0.44684	0.49856	4	4	5	5	20,60,80,100,120,150
0.48451	0.49623	5	4	5	6	20,60,80,100,120,150
0.4978	0.50065	7	5	7	6	20,100,150
0.47932	0.51786	2	1	2	3	20,60,80,100,120

RESULTS

Comparison of Design Study Run Times

	Local Machine	HPRC Cluster
Average Run Time per Case	~15.8 minutes	~15.8 minutes
Total Number of Cases	106,992	106,992
Cases Running in Parallel	2	Up to 300
Total Time	~14100 Hours (~1.61 Years)	~570 Hours (~24 Days)

- Magnetic gear parameters are chosen based on analysis of genetic algorithm's final generation simulation results.
- Unique magnet material design combinations.



CONCLUSIONS

- Used HPRC resources to conduct extensive parametric analysis and optimization of electrical motor and magnetic gear topologies.
- Large numbers of cases can be evaluated in parallel on HPRC's Linux cluster, resulting in a significantly faster optimization process.
- This process can be automated to require minimal human oversight.

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