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Galileo Ferraris' Contest
contest

April 17, 2024

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why electrical machine design as a contest?

- traction motors present a complex *design challenge* due to their multi-physical nature
- a *pre-design tools* become crucial due to more demanding constraints
- new interactions across physical domains (electromagnetic, thermal, structural, acoustic, etc.) require a *multi-physical* approach
- by consequence, different criteria must be considered in the design process, and most often, these are *contrasting* each other as for:
  - torque and temperature
  - rotating speed and mechanical stresses
  - ...

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an *open* environment

- the design process $\rightarrow$ twofold *computationally intensive*: both in the analysis phase (*multi-physical*) and in the optimization one (*multi-objective*)
- the research activity on this topic is wide and such a community needs an *open database* on a technically sound test-case to unify their methodologies
- the electrical machine design seems to be a good candidate for assessing *data-driven methodologies*, mainly but not only in the COMPUMAG society

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why electrical machine design as a contest?

- *V-shaped Internal Permanent Magnet (IPM)* configurations are chosen as a reference
- the motor geometry is described in a unique way by *well-defined rules*, together with its material properties. Supply conditions and circuit data are provided
- the structure will be modelled starting from its *2D cross section*

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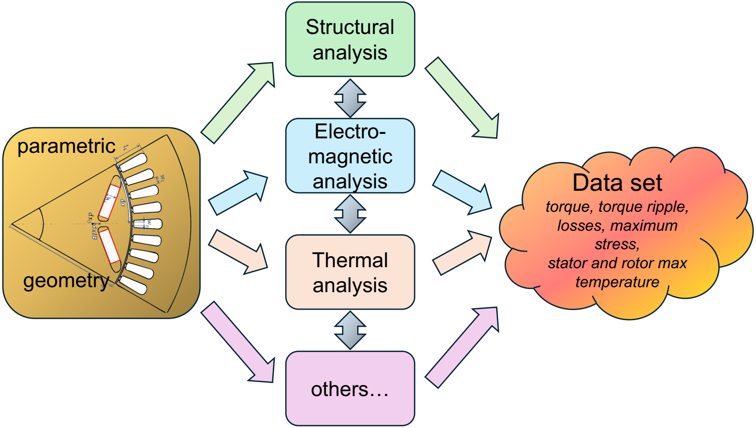
Test case structure

Multi-physics model, from geometry to results

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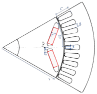
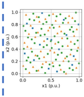
Test case structure

- breakdown of different steps $\mathbf{x} \in \mathcal{R}^p \rightarrow \mathbf{y} \in \mathcal{R}^m$
- all procedures linked in a single `Matlab`® procedure
- available under the Apache Version 2.0 license
- geometric rules to build mesh are controlled to suppress possible *unfeasible* solutions

Step 1
definition of parametric geometry by p real valued arrays
$\mathbf{x} \in \mathcal{R}^p$



Step 2
hierarchical generation of N points



Step 3
creation of motor structure
$\mathbf{x}_k,\ k = 1, \ldots, N$

Step 4
creation of the 2D triangular mesh

FEMM
Lua

Step 5
Multi-physics analysis based on 2D and 3D models

electromagnetic
thermal
structural

Step 6
collection of m results for each configuration
$\mathbf{y} \in \mathcal{R}^m$

results dataset

Workflow

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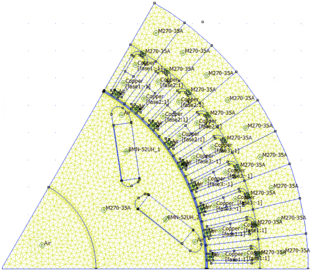
Building of *multi-physics* model

2D mesh

- all physical domains will be analysed starting from the 2*D* mesh created from parameters $\mathbf{x}_k \in \mathcal{R}$
- all results are evaluated by finite element method so that no other numerical method is set between parameters and results



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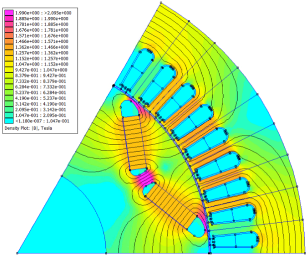
electromagnetic

- nonlinear magneto-static analysis is performed
- several relative positions between rotor and stator (*snapshots*) are considered, enabling the evaluation of torque ripple, magnetic induction waveforms within iron, etc.
- in a first instance, a number of positions (≈ 12) sufficient for the correct evaluation of the torque ripple, will be run.



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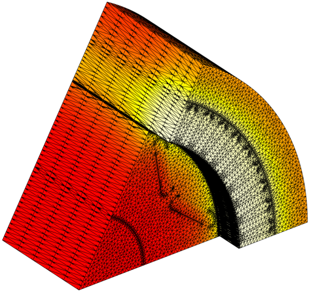
thermal

- $2D \rightarrow 3D$ model compatible with cooling water jacket and potted end windings is created
- thermal in overload (*peak performance*) thermal transient on $T = 10\ \mathrm{s}$ (dominance of copper losses)
- wire winding $\rightarrow$ homogenized material (copper + slot liner)
- heat transfer at the air gap will be considered at the *base* rotational speed *(corner speed)*
- comparison with *state of the art* tools will be provided



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structural

- highest allowed Von Mises stress, corresponding to the maximum rotational speed at a given reference temperature is considered
- permanent magnet is considered as a hanging mass in contact with the external slot
- no relative movement between parts (no sliding between slot and magnet)
- stresses between the rotor core and the shaft are neglected