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Galileo Ferraris' Contest contest

April 11, 2024



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why electrical machine design as a contest?

- among *challenging* problems in design, the one of traction motors is emerging as a multi-physical one
- always more stringent and demanding constraints are driving the structure to new and unforeseen limits and a need for *pre-design tools* is emerging
- new interactions and couplings between different physical domains, electromagnetic, thermal, structural, acoustic, etc., have surfaced, creating the need for *multi-physical* analysis of the structure.
- At the same time, different criteria must be considered in the design process, and most often, these are contrasting each other as for example:
 - torque vs temperature
 - rotating speed vs mechanical stresses in the rotor
 - ...



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- As it is apparent, the design process has become, at least, twofold computationally intensive: one in the analysis phase (*multi-physical*) and one in the optimization one (*multi-objective*)
- a cooperation among research groups requires an *open* databases of results on a technically sound *test-case*
- for these reasons, the electrical machine design seems to be a good candidate problem for assessing *data-driven methodologies* mainly but non only in the COMPUMAG community
- the availability of *open* datasets will allow different research groups to assess their procedures without the need to have the analysis capabilities of the whole multi-physics problem



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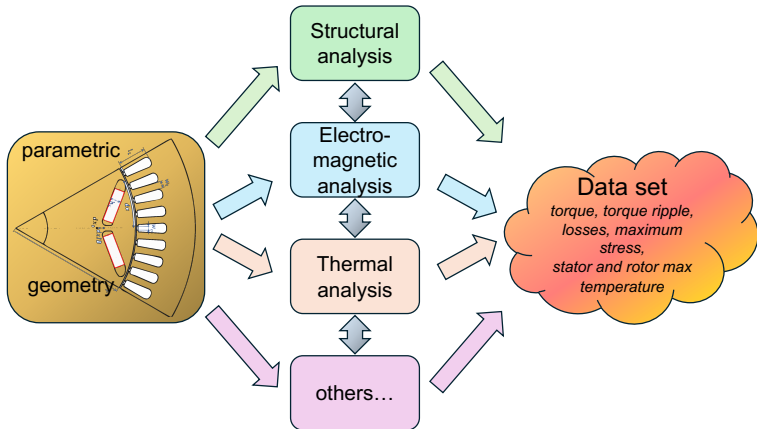
why electrical machine design as a contest?

- Among different possible motor configurations, *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, as well as its material characteristics in all the physical domains involved. Supply conditions and circuit data are provided.
- The structure will be modelled starting from its two dimensional cross section containing the main *factors* that can influence performance.
- The two-dimensional mesh is created having a sufficient number of elements and a distribution able to return an adequate degree of accuracy in all physical domains involved.



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Multi-physics model, from geometry to results

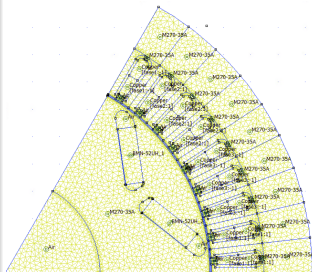




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2D mesh

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

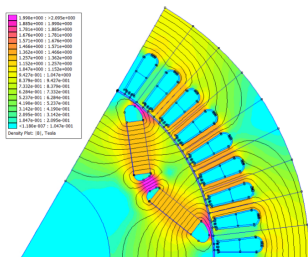




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electromagnetic

- nonlinear magneto-static analysis is based on the two-dimensional mesh
- several relative positions between rotor and stator (*snapshots*) will be considered, enabling the evaluation of quantities like 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.

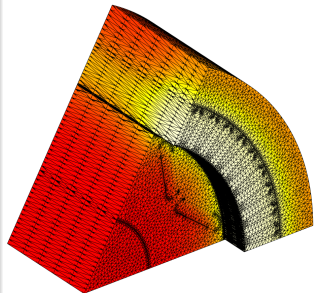




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thermal

- 2D \rightarrow 3D model compatible with cooling water jacket and potted end windings
- thermal in overload (*peak performance*) thermal transient on $T = 10$ 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

- rotor structure considering the maximum rotational speed at a given reference temperature
- the permanent magnet is constrained on the external contact with the slot while it is free on the internal one
- no relative movement between parts is allowed (no sliding between slot and magnet)
- stresses related to the interference between the rotor core and the shaft are neglected

