UNIVERSITÀ DEGLI STUDI DI PADOVA

Politecnico di Torino

Galileo Ferraris' Contest: Thermal Analysis

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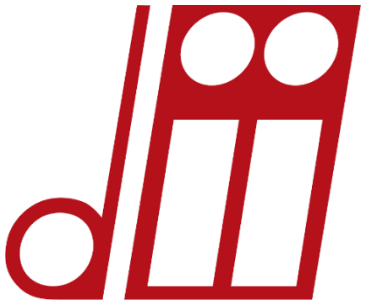
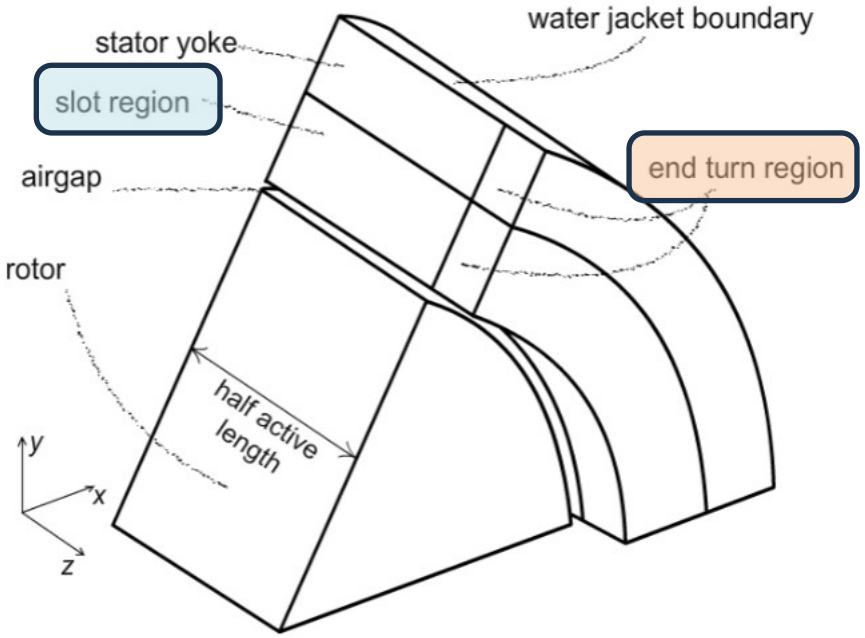


GalFer Contest: Workshop 11/12/2024

Losses – Heat Source of the Thermal Problem

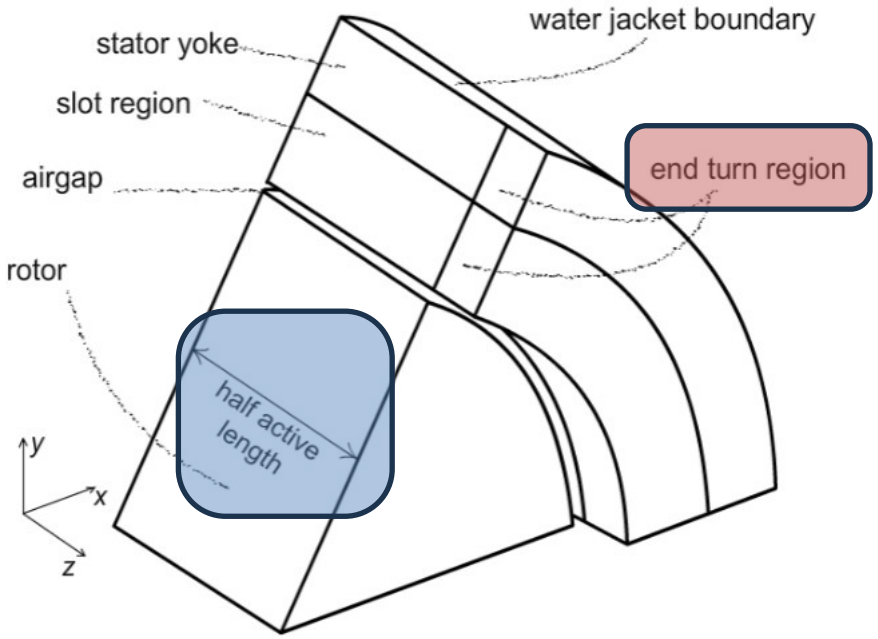


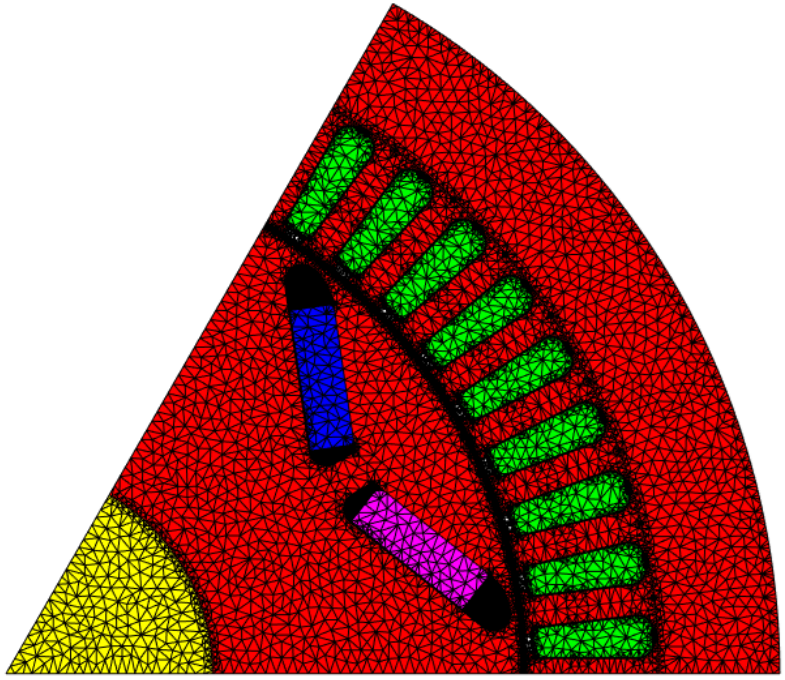
$$P = R_{eq} I^2$$

R_{eq} = equivalent resistance of the slots and end-turn windings

A uniform Power density is assumed in those regions

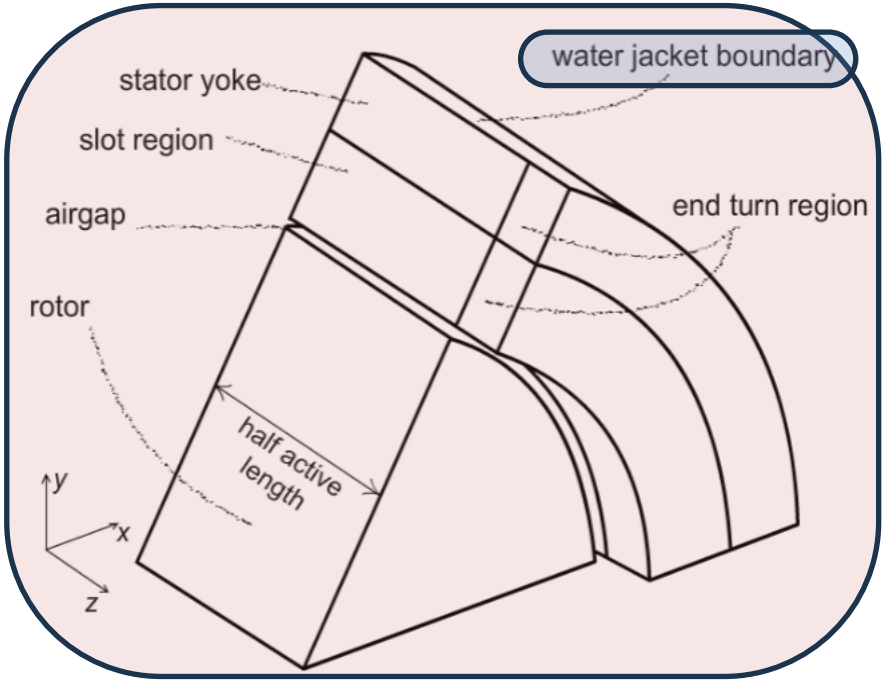
Meshing of 3D Domain





- The 2D mesh of the Magnetic Model is first imported
- The 2D mesh is swept toward the longitudinal direction to create a volume mesh of the (half) active length (prisms with triangular basis)
- This operation is repeated in the opposite direction to create a volume mesh of the end turn region
- Prisms are then converted into tetrahedral elements
- Simmetries are applied as boundary conditions

Thermal FEM Model + Boundary Conditions



HEAT EQUATION

$$\rho(r)c(r)\frac{\partial T(r)}{\partial t} - \nabla \cdot k(r)\nabla T(r) = q(r)$$

CONVECTIVE BOUNDARY CONDICTION

$$n \cdot k(r)\nabla T(r) = h(T_{fluid} - T(r))$$

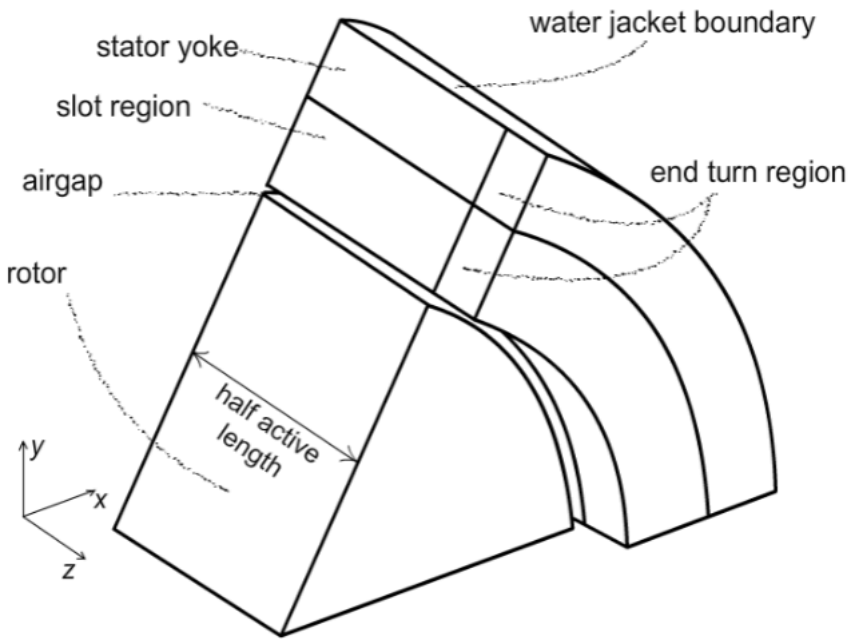
$$h = 2404\,\frac{\mathrm{W}}{\mathrm{m^2K}}$$

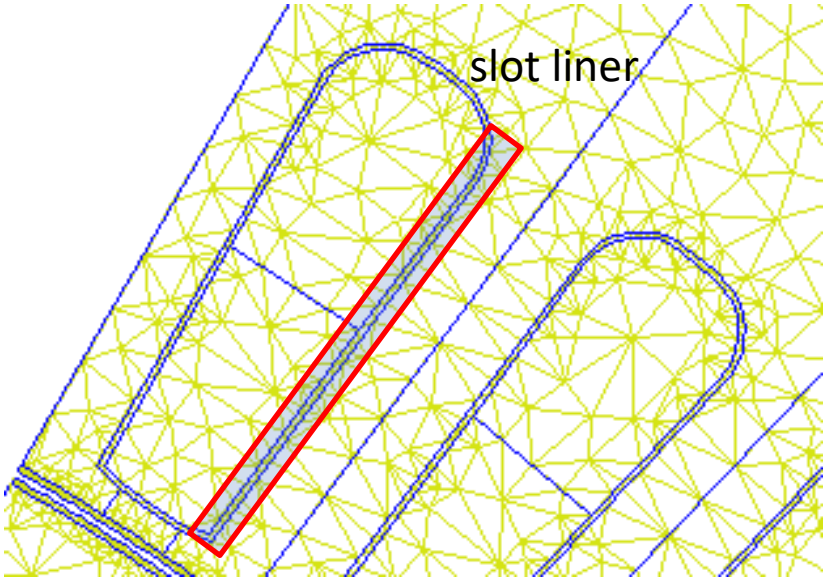
$$T(r) = \sum_{i=1}^{N} \varphi_i(r)x_i \longrightarrow$$

DISCRETIZED PROBLEM (ODE)

$$\mathbf{M\dot{x}} + (\mathbf{K} + \mathbf{H})\mathbf{x} = \mathbf{q} + \mathbf{q_{conv}}$$

Material Parameters





	iron (stator/rotor)	windings (homogenized material)	slot liner	air	magnets
$k \left[\frac{\mathrm{W}}{\mathrm{mK}}\right]$	30	153	1.9	0.03	9
$c \left[\frac{\mathrm{J}}{\mathrm{kgK}}\right]$	460	600	733	700	460
$\rho \left[\frac{\mathrm{kg}}{\mathrm{m}^3}\right]$	7650	4250	1400	1.2	7550

Thermal Transiet Simulations

$$\mathbf{M\dot{x} + (K + H)x = q + q_{conv}}$$

$$\downarrow$$

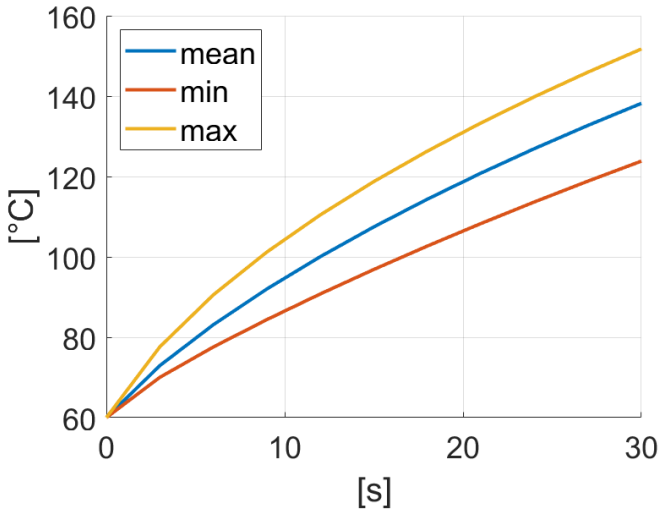
$$\mathbf{\dot{x} = \frac{x_{k+1} - x_k}{\Delta t}}$$

$$\mathbf{\big(M + \Delta t(K + H)\big)x_{k+1} = Mx_k + \Delta t(q + q_{conv})}$$

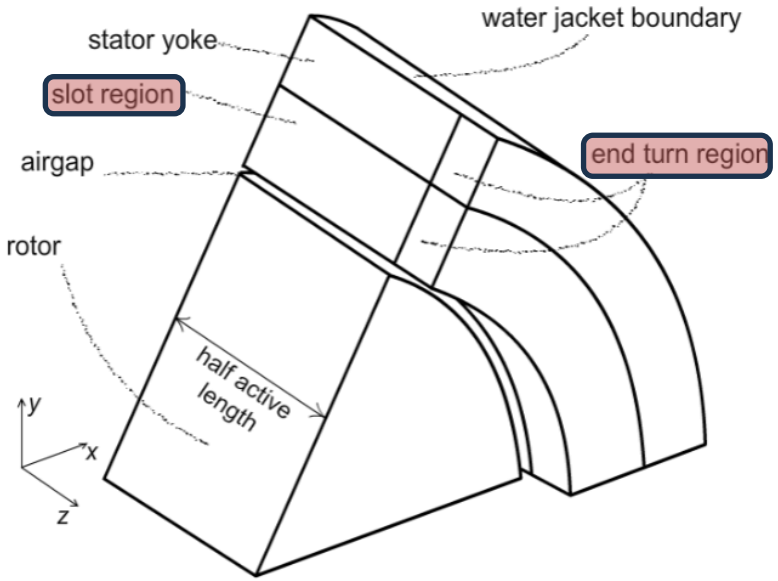
SIMULATION TIME: 30 s

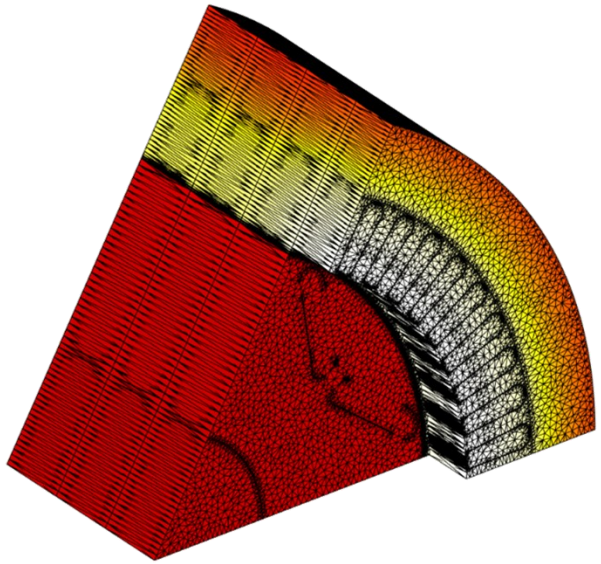
Δt : 3 s

NUMBER OF TIME STEPS: 10



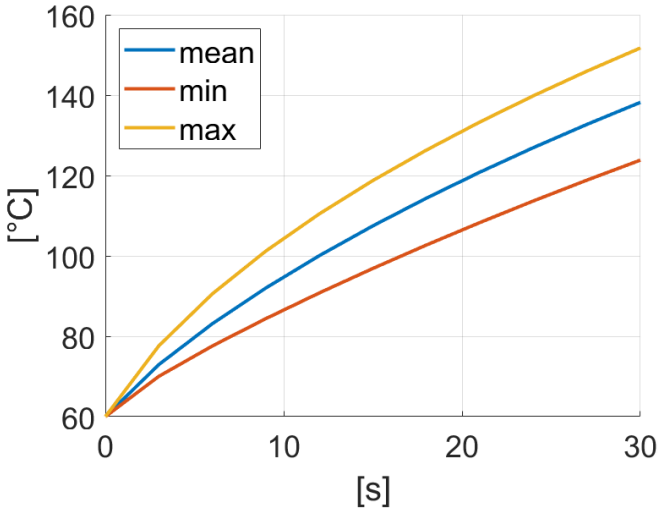
Results: Winding Temperature





SIMULATION TIME:
30 s

OUTPUT QUANTITY:
Tmax @ 30 s



https://cadema-polito.github.io/GalFer_contest/