Modelling Ramp Losses and Magnetization in a Roebel-cable Based HTS Accelerator Magnet Prototype

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Outline

- Motivation
- Methodology
- Results
- Conclusions

Motivation

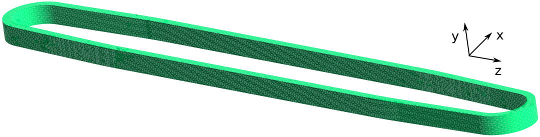

Figure: 3D depiction of FM-0

- 1st HTS Roebel-cable based R&D magnet: Feather M-0
- EuCARD-2 project lead by CERN
- Predicting magnetization and ramp losses is important
- Need for efficient modelling tools and methods arises

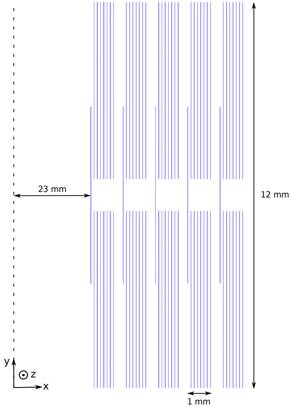

Figure: Modelling domain

Methodology

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  Subjected to constraints on J, and ramp current
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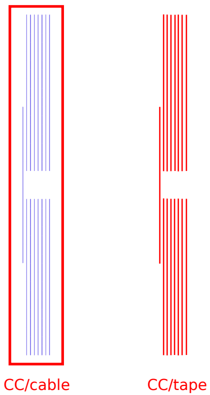
- Minimization carried out using Interior point optimizer (IPOPT)
- Simulation tool was programmed in C++ using the Riemannian manifold interface of Gmsh.

Simulation approaches

- Bean model:
  1. Ramp current constraint on each cable (Bean CC/cable)
  2. Ramp current constraint on each tape (Bean CC/tape)



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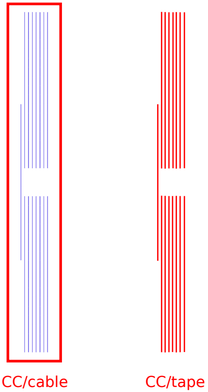
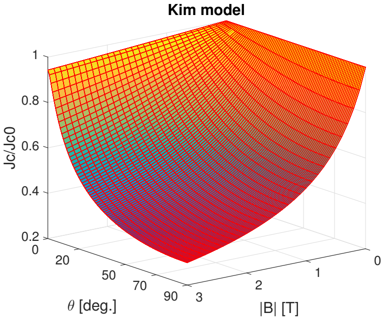
- Kim model:
  3. Ramp current constraint on each cable (Kim CC/cable)
  4. Ramp current constraint on each tape (Kim CC/tape)



$$J_c(B_\parallel, B_\perp) = J_{c0}\left(1 + \frac{\sqrt{k^2 B_\parallel^2 + B_\perp^2}}{B_0}\right)^{-\beta}$$

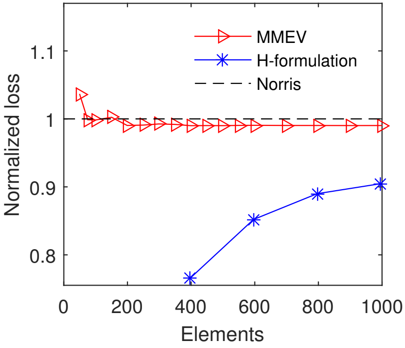


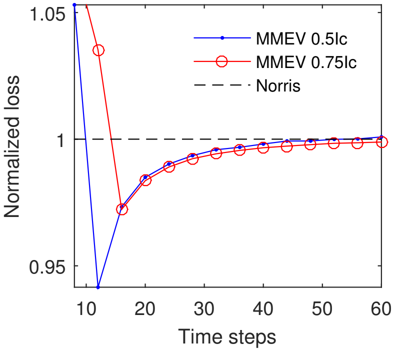
Results

- Benchmarking against Norris strip formula
- Current distribution in modelling domain
- Magnetization in magnet's center
- Ramp losses

Benchmarking against Norris strip formula: Bean model

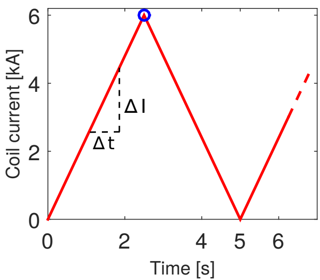
- Convergence analysis:
  - Loss vs. elements
  - Loss vs. time-steps (integrating $P(t)$ over cycle)

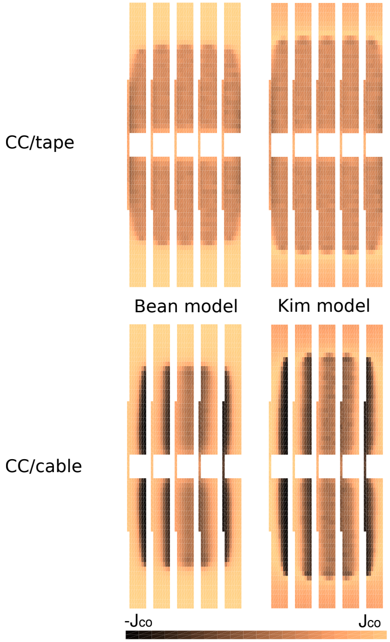




Current distribution in modelling domain

- Current distributions were computed for each time-step
- Each Δt corresponds to change ΔI in ramp current





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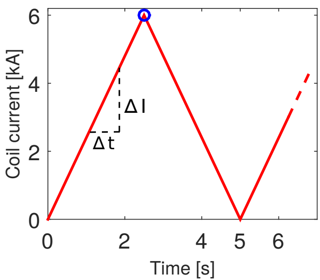
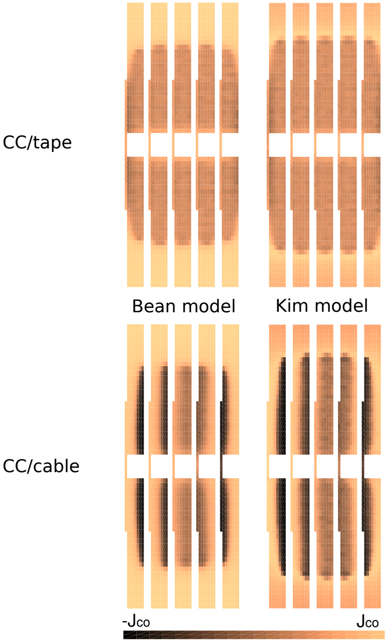
- Coil I_c was determited with Kim model: 11.5 kA





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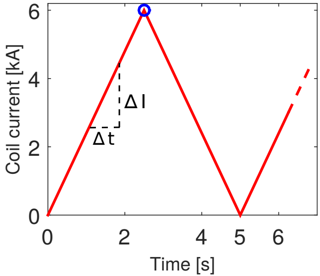
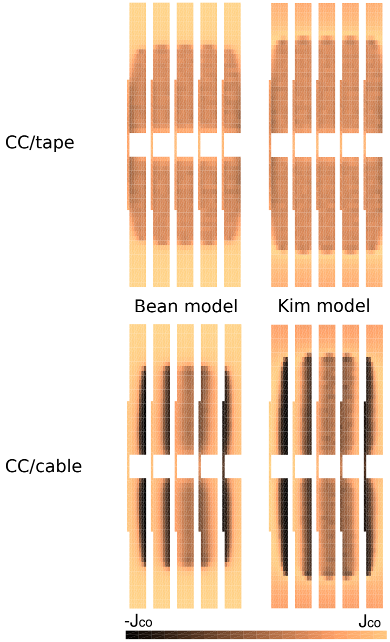
- Cases result in different current penetration



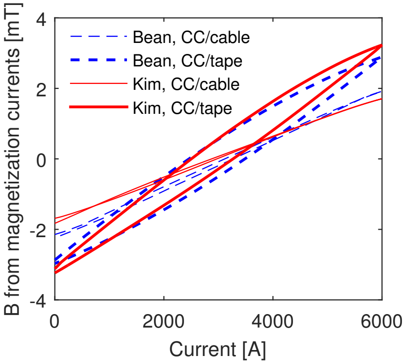


Magnetization in magnet's center

- Computed from the magnetization currents: $J - J_{UNIFORM}$
- Tape-wise current condition resulted in largest magnetization field: $\sim$3.2 mT (Kim model)

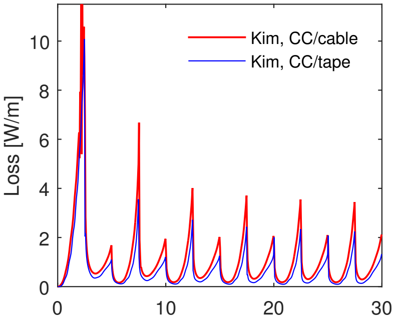
Table: Kim CC/tape - normalized magnetization

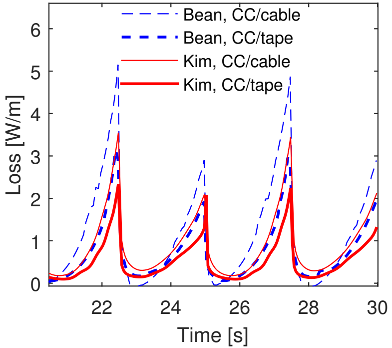
CC/	Kim	Bean
tape	1	0.89
cable	0.53	0.59



Ramp losses

- Tape-wise current condition resulted in smallest loss per cycle: ~ 2.47 J/m (Kim)





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tape	1	1.43
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- 27 km long string of magnets would generate $\sim$67 kWh heat energy per cycle (Kim CC/tape)

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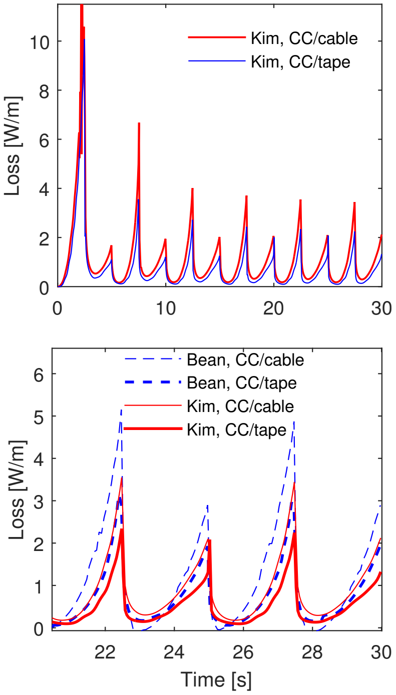

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  - Contact resistance
  - Transposition length
  - Current terminal

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- Experiments will give us more information
- MMEV-solver with IPOPT performed well
  - Outlook: Using parallelization, more complex magnets could be simulated rapidly

CHEERS!