htsmod2020:314607

Impact of strain-dependent J_c on SCIF in 2G HTS magnets

Funding: DGAPA-UNAM, PAPIIT 2021 #IN108021

Frederic Trillaud[1], Edgar Berrospe-Juarez[2], Victor M. Zermeño[3], Francesco Grilli[4]

[1]: Instituto de Ingeniería, UNAM, CDMX 04510, Mexico; [2]: École Polytechnique de Montréal, Montréal, Québec H3T 1J4, Canada; [3]: MKT, Cologne , Germany; [4]: Karlsruhe Institute of Technology, Karlsruhe 76131, Germany

Abstract – 2G HTS tapes are strong candidates for the development of future high magnetic field magnets. However, for such applications, the field stability and quality affected by the presence of large Screening Current-Induced Field (SCIF) and the mechanical degradation of the tape during the magnet operations are issues to be overcome for providing a reliable system for users of high magnetic field laboratories. A new model is proposed to simulate the magnetic and mechanical behavior of 2G HTS insert magnets under very high magnetic fields. This model includes the strong coupling between the electromagnetic and mechanical physics of REBCO tapes via the definition of their *n* index and critical current density J_c. The case study is the Little Big Coil (LBC) which broke recently the record of the strongest continuous magnetic field achieved thus far.

Case study: Little Big Coil (LBC)

Record at **45.5 T** central field

Insert HTS magnet (Fig. 1):

- 4 mm width REBCO tapes
- Average I_c at 77 K, 0.6 T: ~54 A
- 12 racetrack coils
- Background solenoidal field: 31 T
- Quench at 245 A

Fig. 1: LBC [1].

Strongly coupled mechanical and magnetic Model

- Axisymmetric, 1/4th of magnet cross-section => 6 pancakes (see Fig. 2)
- Current ramp rate: 0.068 A/s
- Target field: 45 T
- Electromagnetic model: homegeneous *T-A* formulation [2]
- Mechanical model: elastoplastic (nonlinear $\boldsymbol{\sigma}$-$\boldsymbol{\varepsilon}$ curve)
- **Strong coupling** carried out by the critical current J_c and the *n* index both depending on strain $\boldsymbol{\varepsilon}$ (see Fig. 3)
- Critical current depending on field magnitud and orientation through the Kim relation

Mechanics ⟷ Magnetics

$$J_c(\mathbf{B},\varepsilon) = \frac{J_{c0}}{\left(1+\sqrt{\dfrac{\gamma^2 B_\parallel^2 + B_\perp^2}{B_0^2}}\right)^{\alpha}} \times J_{c,\varepsilon}$$

Normalized

Two mechanical assumptions have been considered: 1) the tapes are glued together (bulk model), 2) Some block of tapes are radially free to move respectively to others (semi-free model)

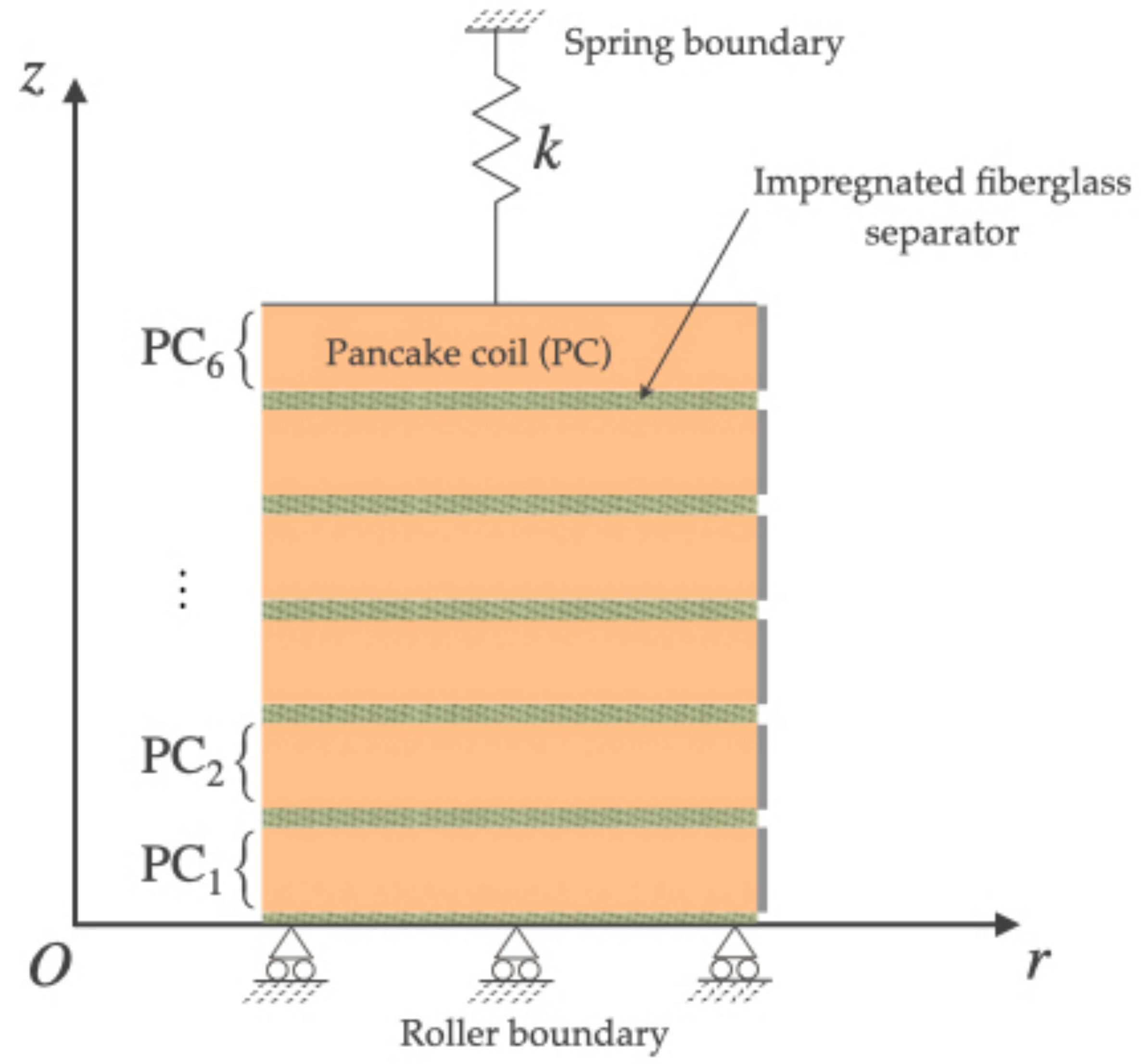


Fig. 2: Axisymmetric 1/4th model of LBC

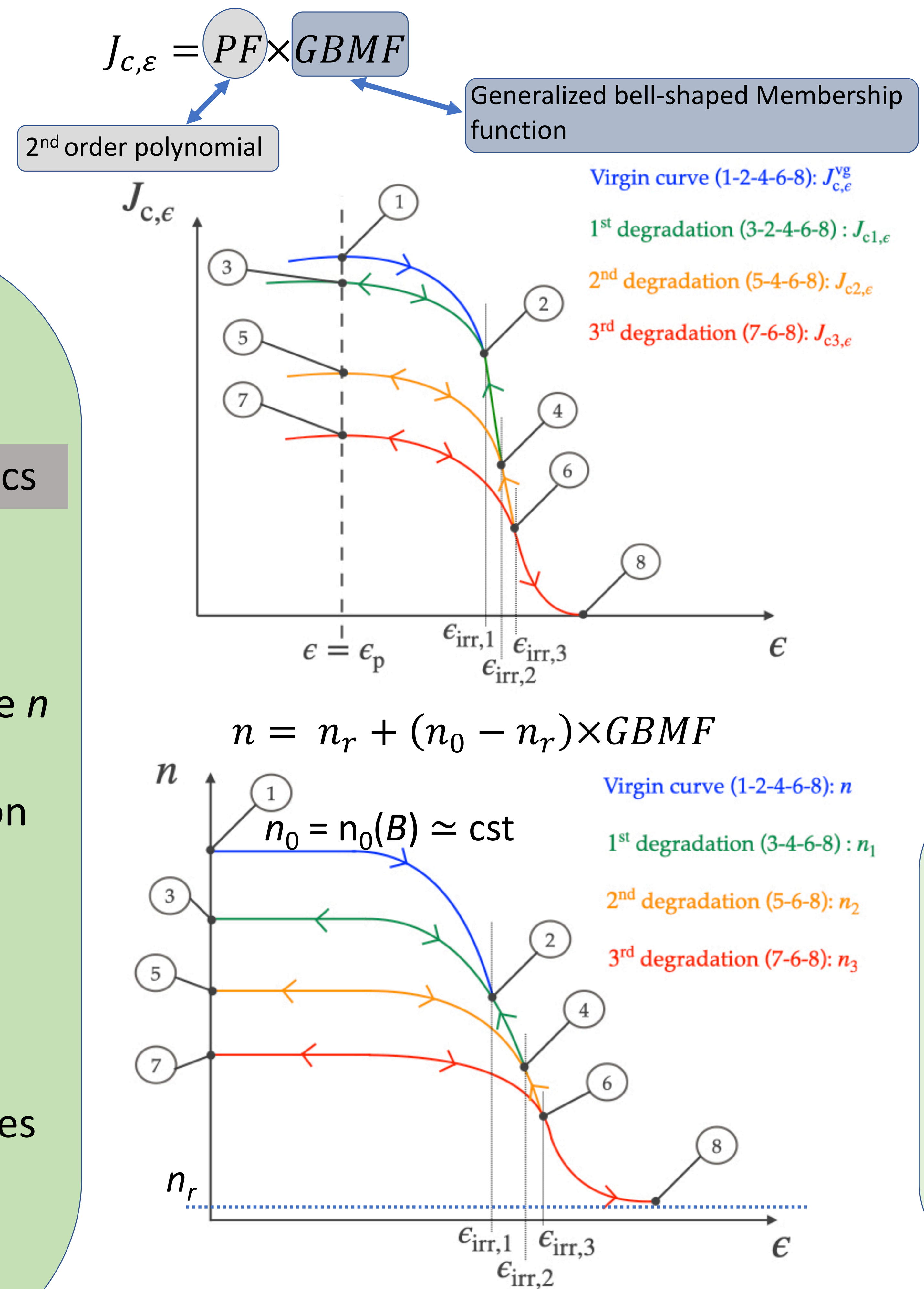
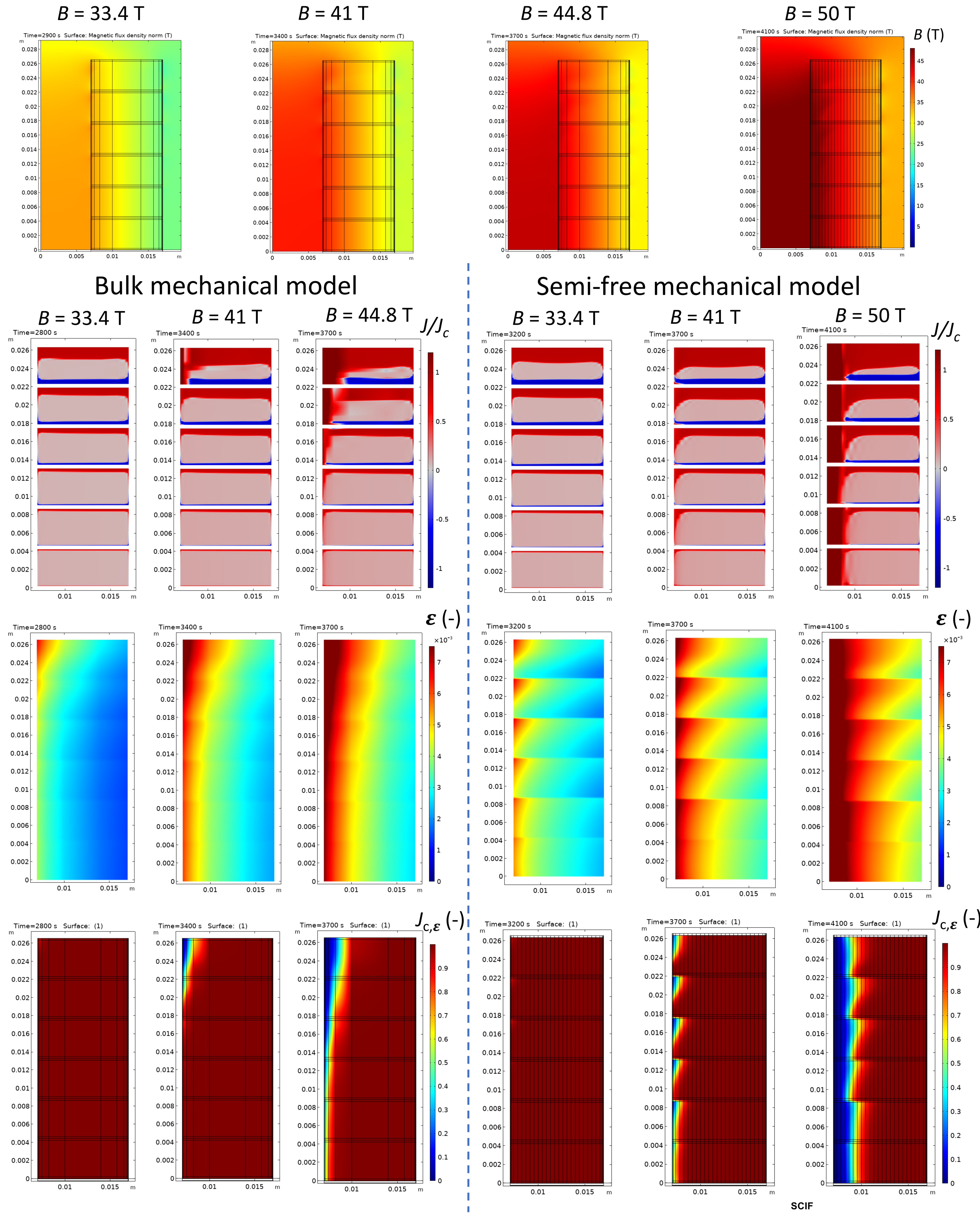


Fig. 3: Model of mechanical degradation of J_c and *n* index accumulated from 1 to 8



Conclusion

The bulk mechanical model is able to catch the initial condition leading to a quench at around 240 A (compared to the experimental 245 A). By freeing the movement of some of the tapes, the peak central field is increased to 50 T before the magnet reaches a similar initial quench condition. The impact on the SCIF is mild since the degradation remains local (Fig. 4) .

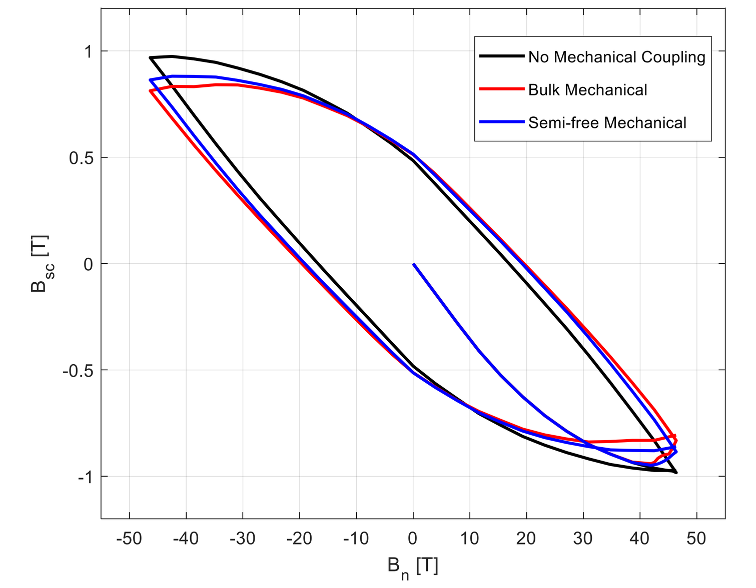


Fig. 4: SCIF comparing models taking the reference as a the model without mechanical coupling

[1]: Hahn, S., Kim, K., Kim, K. et al. "45.5-tesla direct-current magnetic field generated with a high-temperature superconducting magnet". Nature 570, 496–499 (2019)

[2]: E. Berrospe-Juarez et al. "Advanced electromagnetic modeling of large-scale high-temperature superconductor systems based on H and T-A formulations". SUST Vol. 4, No. 4, 2021