Models for optimization and AC Losses Analysis in a 2G HTS Cable

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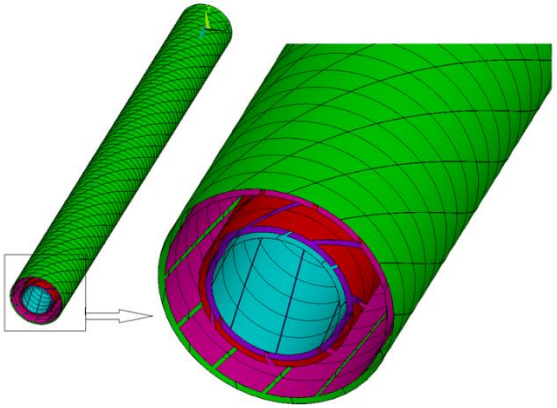
Numerical methods can handle any geometrical configuration, time-dependent problems, and both linear and nonlinear cases.

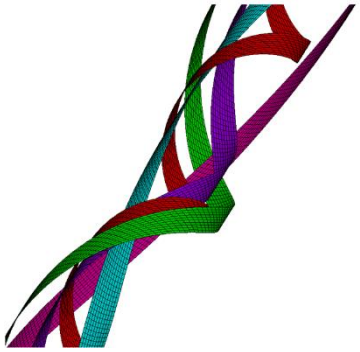
The FEM models using the ANSYS Emag software to solve the transient electromagnetic problem for complex study (optimization and AC losses) of the 2G HTS cable were developed.

Two 3D FEM models were developed to optimize the geometry of both coaxial and triaxial 2G HTS cables. In addition, with the help of the 3D FEM model, we can calculate the hysteresis losses in a NiW substrate of 2G HTS tapes of the cable. The transient 2D FEM model was developed and used for the calculation of AC losses in the cables and stacks of 2G HTS tapes. For the correct calculation of the AC losses, it is important to determine the parameters in an empirical expression describing the critical current density of the 2G HTS tapes dependence from the vector magnetic field and its non-uniformity across the tape width.

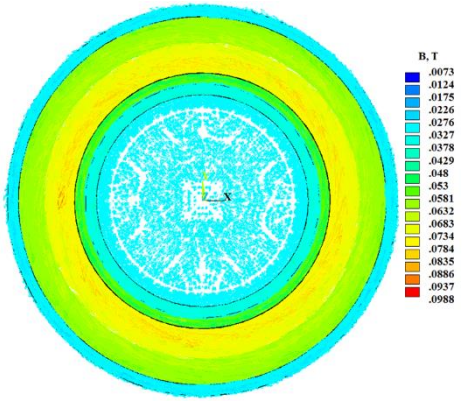
3D FEM model for geometry optimization of the cable



The elements of HTS layers of the tapes of end part of the coaxial cable in detailed 3D FEM model.



Several meshed tapes in layers of the cable.



Magnetic field in the cable.

10 mesh elements across the HTS layer width of the tapes were used.

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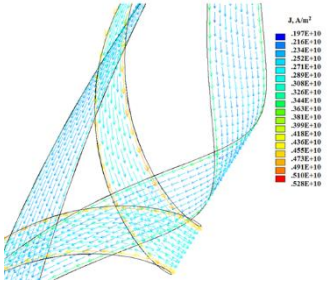
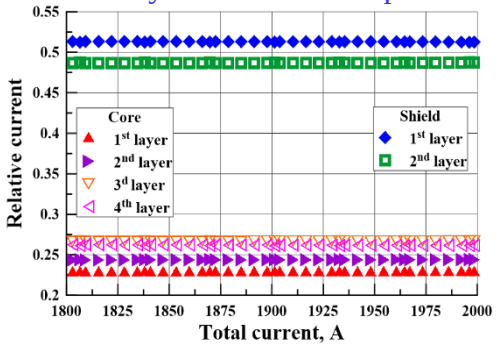
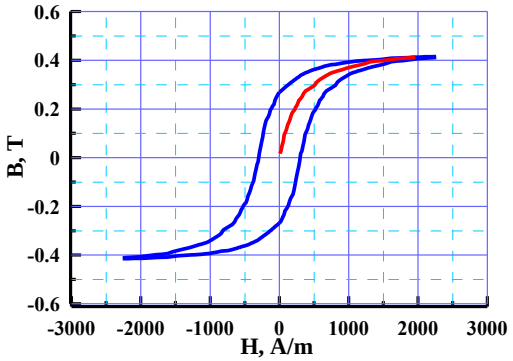


Current in several tapes of the cable.

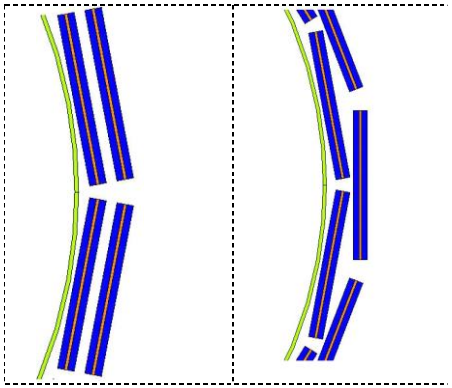


Measured relative current distribution in layers of the cable core and the shield of the HTS cable versus amplitude of the total current.

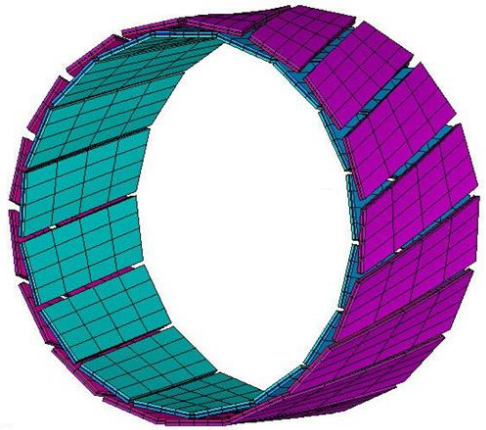
3D FEM to calculate hysteresis losses in a NiW substrate of 2G HTS tapes of the cable



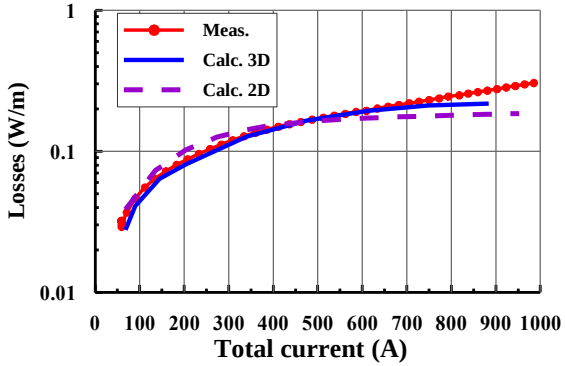
Substrate of 2G made from NiW substrate has weak magnetism .
Data measured in VNIIKP



2D FEM model



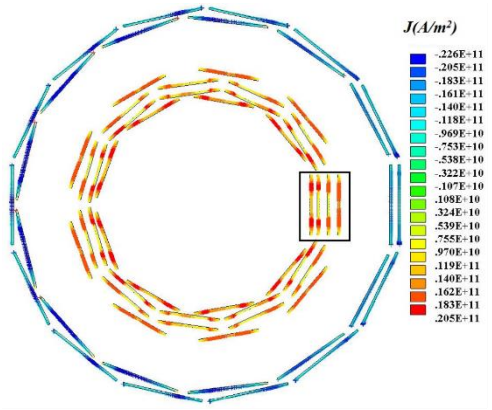
3D FEM model



4 mesh elements across the HTS layer width of the tapes were used.

Calculated hysteresis losses in the substrate and measured total losses in the HTS cable versus amplitude of total current at I<0.3 Ic.

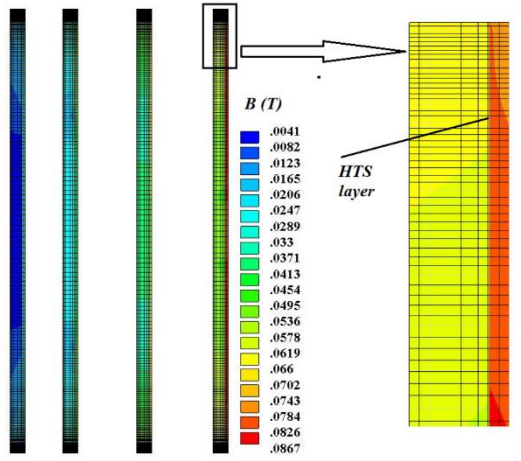
2D FEM model for losses calculation in HTS layers of the tapes of the cable



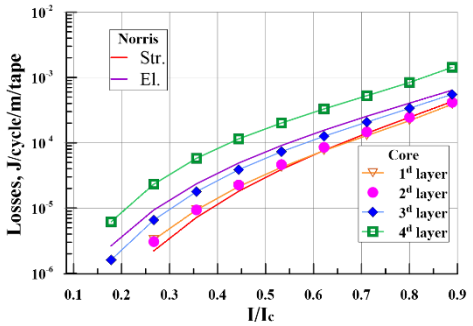
The current density distribution in the HTS layers of the cable(4-layer core and the 2-layer shield).

For realization of the possibility to calculate losses in the layer of the 2G HTS tape, the FEM model using ANSYS needs to include the nonlinearity between resistivity (ρ) and current density (J) of the superconductor. This can be realized by iteration algorithm.

300 mesh elements across the HTS layer width of the tapes were used.



Dependencies of magnetic field in the tapes of the core .



Calculated losses with Norris model and by FEM model in layers of the core of the cable versus ratio I/Ic.

Conclusion

The main disadvantage of the licensed software is the long time of calculation of the detailed 3D FEM models. This limitation can be overcome by the use of some open-source software products that usually do not suffer from such shortcomings because of the possibility of changing the mathematical models of the investigated processes and a wide choice of algorithms and methods for generating finite element meshes, analyzing their quality, optimizing for different criteria, and subsequent solving of systems of linear equations.