Overview of AC Losses in Coated Conductor Stacked Tape Cables for Fusion Magnets

D. Uglietti

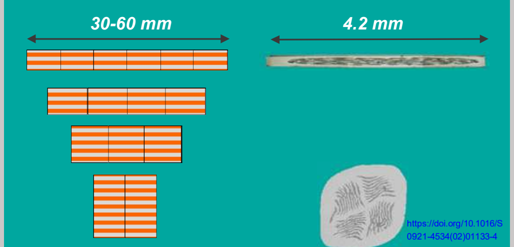
Ecole Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-5232 Villigen PSI, Switzerland

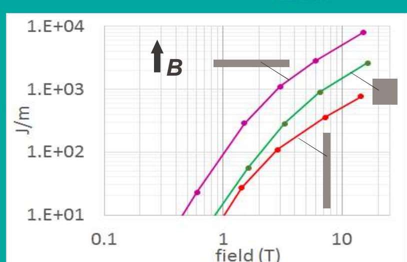
INTRODUCTION — Cables for fusion magnets carry large current, in the range 30 kA to 100 kA.
How to arrange hundreds of coated conductor (REBCO) tapes? By tape stacking, in **one stage** or **two stages** stacked-tape cables.
What about AC losses? https://doi.org/10.1016/j.cryogenics.2020.103118

One-stage monolithic cable   tape ⇒ cable

All tapes are arranged in a large stack, eventually in multiple columns. Therefore, **all tapes are fully coupled** at any sweep rate, similar to filaments in Bi2223 tapes. AC losses are equivalent to the hysteretic loss in a superconducting bar of the same dimensions.

Loss management — In analogy to Bi2223 strands, losses can be controlled by varying the aspect ratio: high aspect ratio in magnet sections where the field is almost parallel to the long side, square in other cases.
https://doi.org/10.1109/TASC.2003.812398

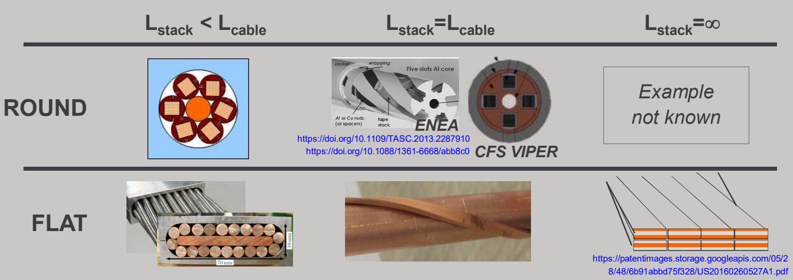




WARNING: loss (J/m³) is proportional to the size (for $B>B_p$). It follows that monolithic cables have much higher losses (in J/m³) than Bi2223 tapes because of the much larger size.

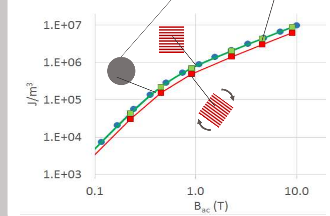
Two-stages cables   tape ⇒ stack ⇒ cable

Aspect ratio can be round or elongated (flat cable). Tapes are arranged in stacks (twisted or non-twisted), resulting in six combinations, depending on stack and cable pitches (L_{stack}, L_{cable}):.



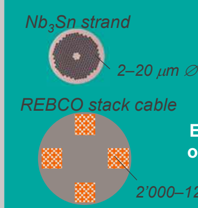
Uncoupling the tapes in each stack is ineffective; therefore, a stack can be considered as a huge filament. Instead, **uncoupling the stacks** has a moderate effect on losses.

Stack loss — not much difference (<30%) among twisted and non-twisted: **L_{stack} is irrelevant**

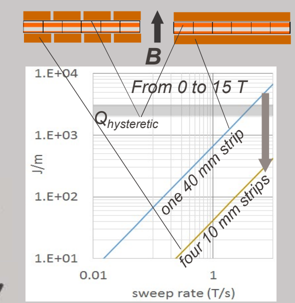


Loss managements

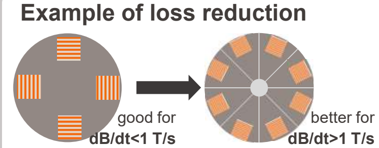
— Loss reduction strategies for cables are the same as in LTS strands:



	$Q_{hysteretic}$	$Q_{coupling}$	Q_{eddy}
Nb_3Sn strand	Very small (fine filaments)	Stacks (or filaments) are uncoupled only if, for a given dB/dt, the pitch is short and transverse resistivity high: $\frac{2R\delta J_c}{L_t} \gg \frac{dB}{dt}$	Negligible (very thin copper)
REBCO stack cable	Enormous, because of the large tape and stack dimensions		Large only at high dB/dt, in fact:
Reduction by:	Distribute the tapes in smaller stacks	Shorten teist pitch, increase transv. res.	Subdivision



Example of loss reduction



- $Q_{hysteretic}$ reduced by a factor 1.4
- $Q_{coupling}$ strongly reduced by higher transverse resistivity (extending operation range to high dB/dt)
- Q_{eddy} reduced roughly by at least a factor 4

CONCLUSIONS

- Uncoupling tapes in a stack is ineffective. Therefore, stacks (twisted or not) can be considered as gigantic filaments, thus leading to colossal hysteretic losses.
- One-stage cables have the highest losses (only for TF?), of the order of MJ/m³ of volume of tapes,.
- AC losses in two-stage tape cables are formally analogous to losses in strands, Uncoupling stacks (twisting or transposing) has a moderate effect on AC losses.
- Two-stage cables can achieve moderate loss reduction roughly 5–10 times reduction (enough for CS?).

MT27 WED-PO2-712-03