UNIVERSITY OF TWENTE. EMS UNIVERSITEIT GENT iter ERASMUS MUNDUS FUSION DC

# Strand level modeling on AC loss and current distribution of prototype EU DEMO TF conductors


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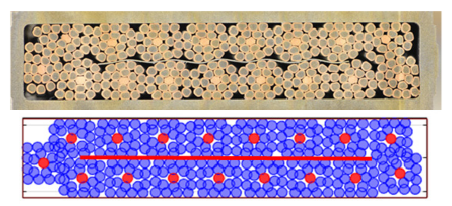
## Introduction

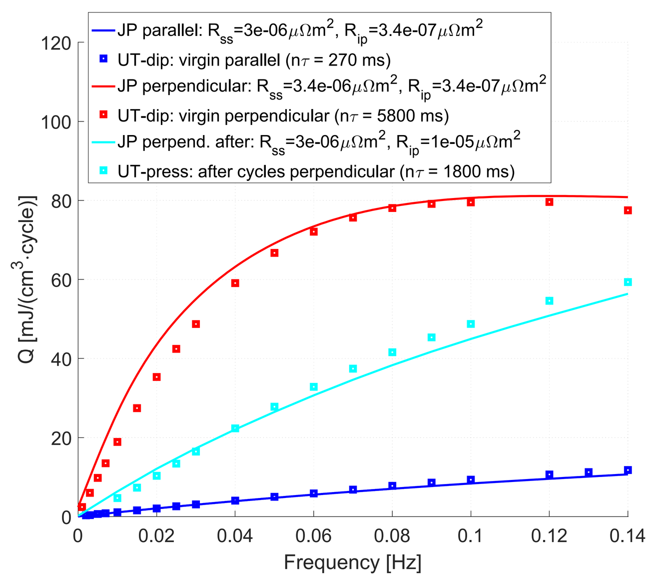
The development of the Toroidal Field coils of the upcoming European DEMO reactor is under the coordination of the EUROfusion Consortium. The Swiss Plasma Center (SPC) and ENEA-Fusion produced two new cable concepts, RW1 (react and wind) and WR1 (wind and react) with rectangular cross section, inspired by existing concepts of $Nb_3Sn$ Cable-in-Conduit Conductors (CICCs). The prototypes have been tested for DC transport current and AC loss in the EDIPO facility (SPC) and for inter-strand contact resistance and AC loss at the University of Twente. The code JackPot-ACDC developed at the University of Twente is used to model the conductor geometry and to study the electro-magnetic behavior. Experimental results are used to calibrate and benchmark the simulations.

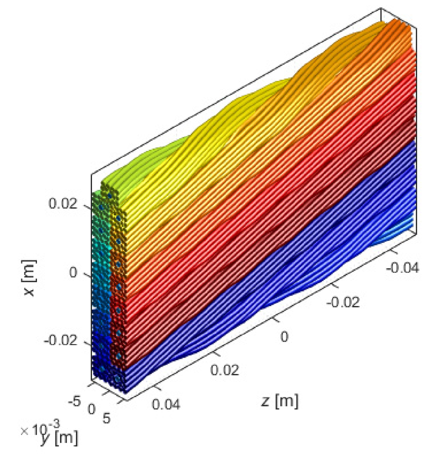
The analysis of coupling loss and current distribution shows the impact of the magnetic field orientation and the rectangular shape of the conductors, focused on possible issues on the stability and performance. One notable outcome of the study is the maximum peak electric field level in the conductors, depending on the magnetic field orientation, compared with ITER CS conductors of previous JackPot studies. This comparison gives an indication of the stability performance of the new DEMO designs.

## RW1 (react and wind) conductor model



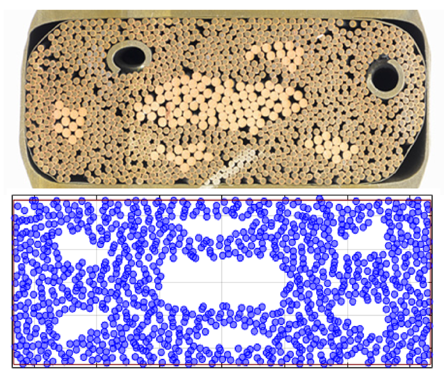
Cross-sections of the RW1 sample as tested at UT and the JackPot geometry used for the simulations. Red dots are copper strands, while the red line is a representation of the steel strip located in the center of the conductor.



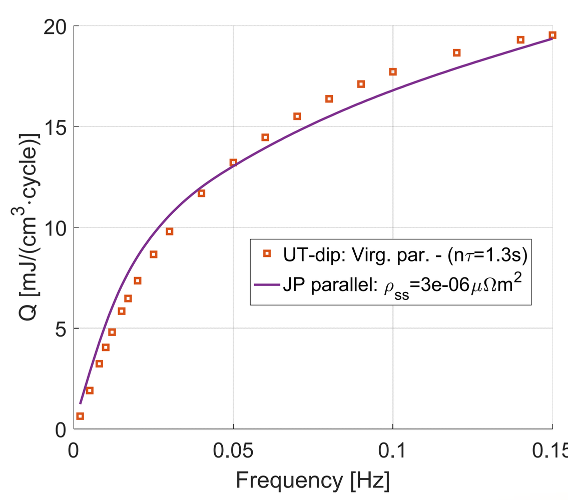



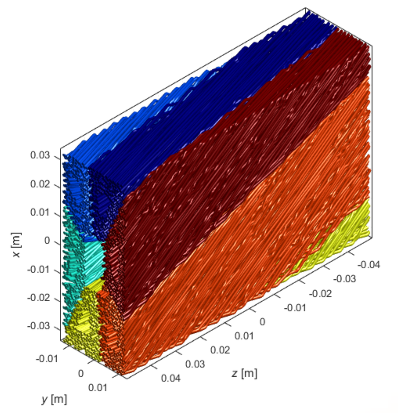
AC loss calculated with JackPot, the experimental points are measurements performed in the Press and in the Dipole set up of the University of Twente

## WR1 (wind and react) conductor model



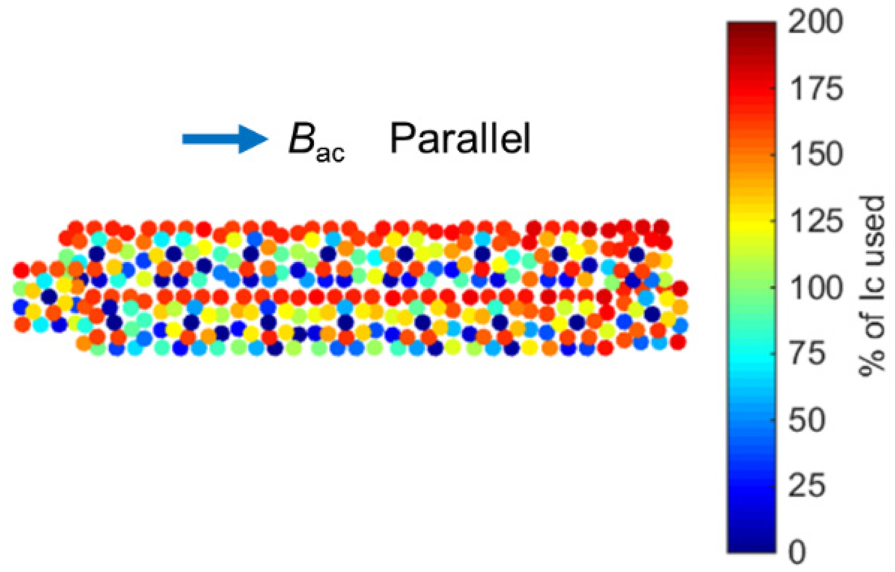
Cross-sections of the RW1 sample as tested at UT and the JackPot geometry used for the simulations. Only superconducting strands are plotted. The channels are not considered in the simulations.

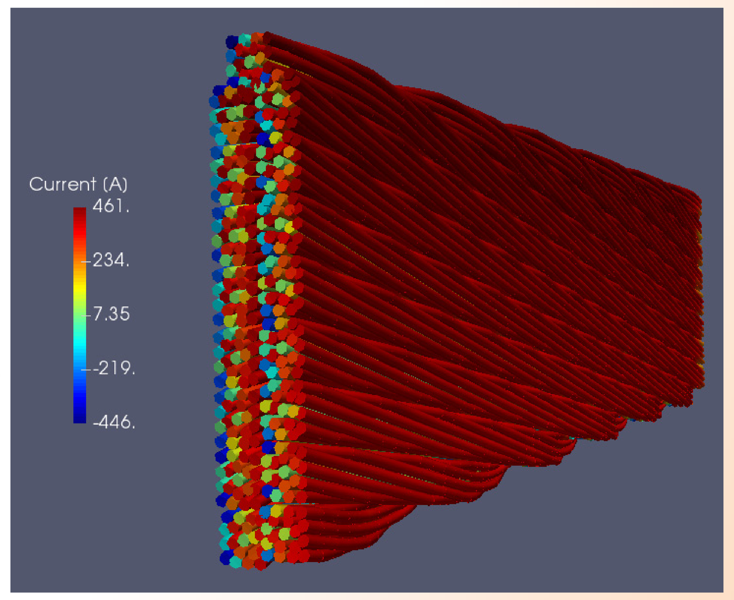


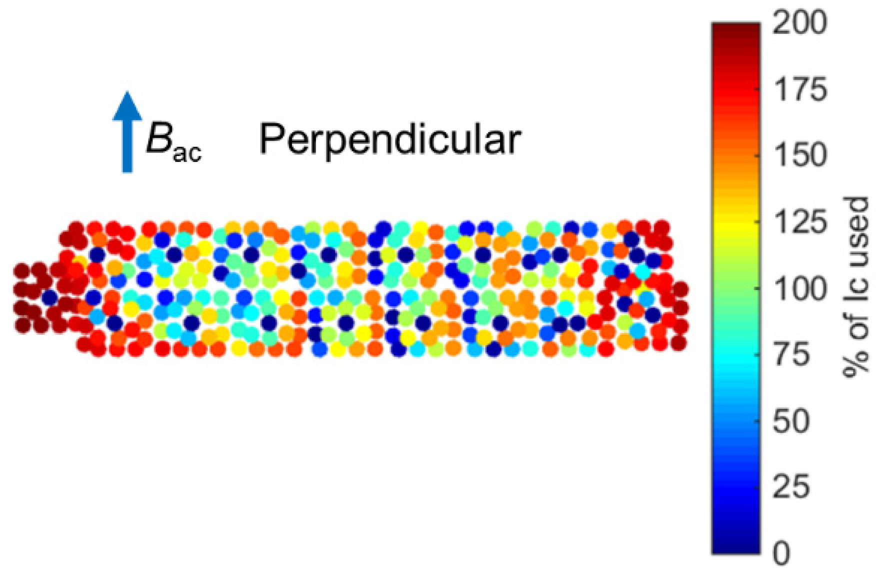



AC loss calculated with JackPot, the experimental points are measurements performed in the Dipole set up of the University of Twente.

## RW1 (react and wind) stability analysis

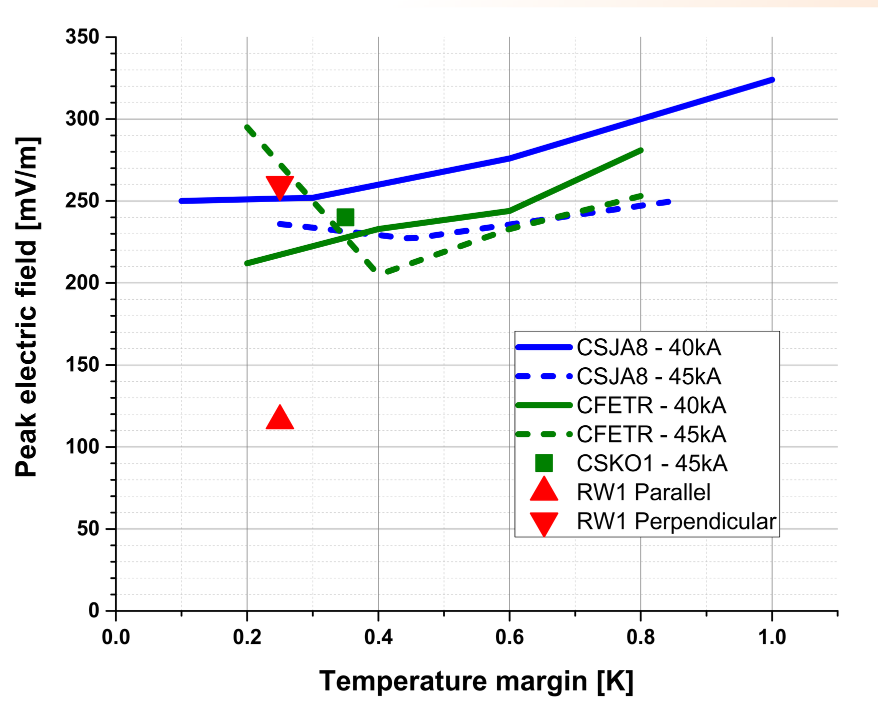




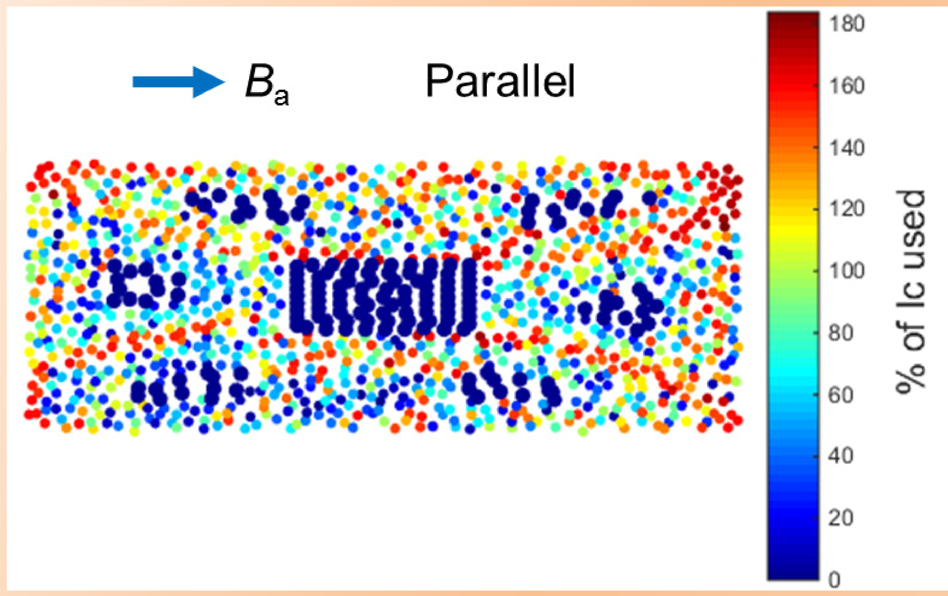

Cross-section of the conductor in the middle of the sample during stability test. The plot shows the distribution of the current as ratio $I_{st}/I_c$ (%) at the maximum peak power. Coupling currents follow different paths depending on the magnetic field orientation. $B_{ac}$ in perpendicular orientation generates higher coupling currents than in parallel configuration.

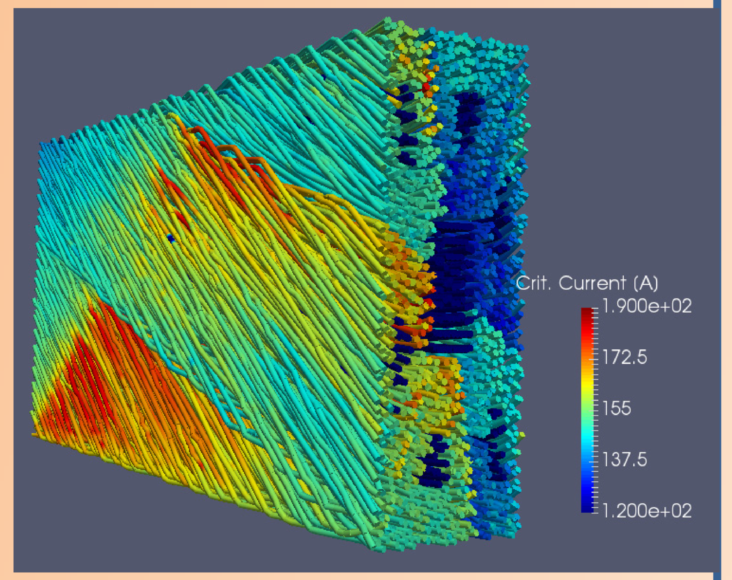
The background magnetic field $B_{dc}$ = 12 T and current $I_{op}$ = 60 kA. The calculated $T_{cs}$ = 8.45 K is comparable with CS conductor tested in SULTAN facility.

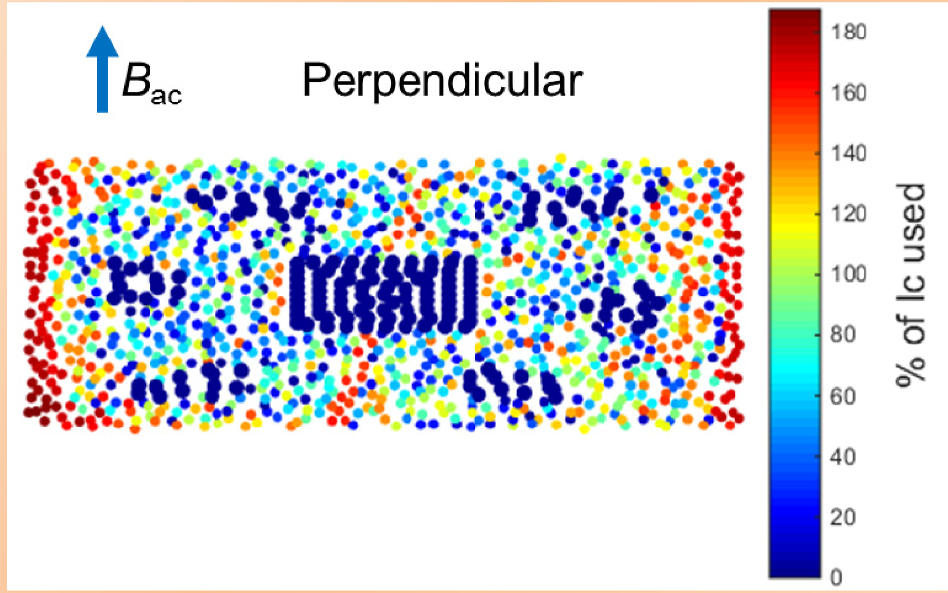



Comparison of the peak electric fields among several ITER type $Nb_3Sn$ conductors and the RW1 conductor in parallel and perpendicular applied pulsed field configurations. Pulse field period $t_{pulse}$ = 0.128 s. Assuming a similar electric field threshold for RW1 sample and CS conductors, in perpendicular configuration the pulse field probably leads to a quench. In parallel orientation the RW1 sample has better performance than the ITER CS conductors.

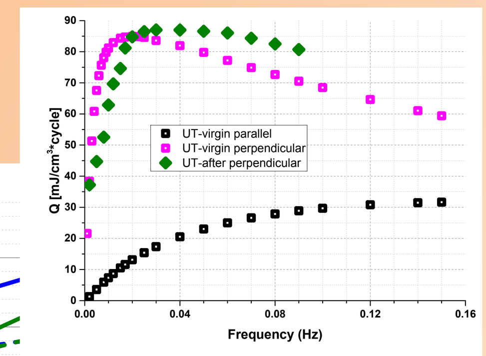
## WR1 (wind and react) stability analysis

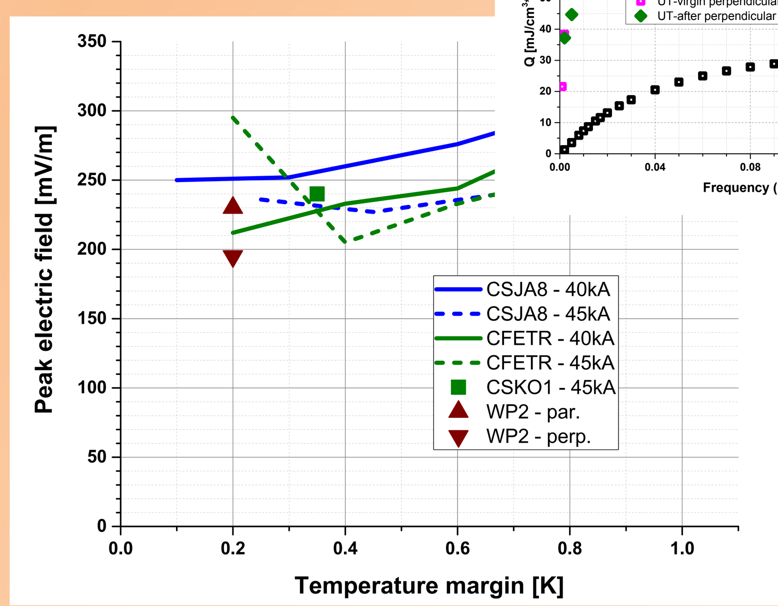





Cross-section of the conductor in the middle of the sample during stability test. The plot shows the distribution of the current as ratio $I_{st}/I_c$ (%) at the maximum peak power. Coupling currents follow different paths depending on the magnetic field orientation. The background magnetic field $B_{dc}$ = 11.8 T and current $I_{op}$ = 80 kA. The calculated $T_{cs}$ = 8.45 K is comparable with CS conductor tested in SULTAN facility.






Comparison of the peak electric fields among several ITER type $Nb_3Sn$ conductors and the WR1 conductor in parallel and perpendicular applied pulsed field configurations. Pulse field period $t_{pulse}$ = 0.128 s. The electric field seems critical in both configurations. The reason is related to the very high $n\tau$ in perpendicular direction and the following decrease of the coupling loss at higher frequency.

The conductor performance is comparable to the ITER CS conductors at high frequency. However, at low frequency in perpendicular configuration the high $n\tau$ may cause instability. This needs to be further evaluated.

## Conclusions

- The rectangular geometry causes different coupling losses and $n\tau$ values depending on the magnetic field orientation.
- The anisotropy of the conductors is also reflected in the stability. The different magnetic field orientation has an influence on the peak electric field reached during the MQE simulation. In the stability performance also the strand diameter, the number of strands and the petal wrap can play a role influencing the current redistribution inside the conductor. The stability of the WR1 is comparable with the ITER CS conductors (at high frequency), while the RW1 has better performance than CS cables in parallel configuration.
- In order to use a rectangular geometry, it is necessary to carefully evaluate the possible magnetic field fluctuations and their orientation in order to minimize possible stability issues and needs to be further evaluated for magnetic fields with higher amplitude and lower ramp rates.

## Contacts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