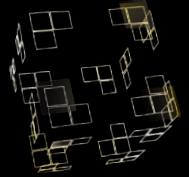
UNIVERSITY OF TWENTE.

Bending of CORC cables, Experiments and Modeling

V.A. Anvar[1, 2], K. Ilin[1], K.A. Yagotintsev[1], M.S.A. Hossain[2], D.C. van der Laan[3], J. Weiss[3], T.J. Haugan[4], A. Nijhuis[1]

1 University of Twente, Faculty of Science & Technology, Enschede, The Netherlands
2 University of Wollongong, Wollongong, Australia
3 Advanced Conductor Technologies and University of Colorado, Boulder CO, USA
4 US Air Force Research Laboratory, Wright Patterson AFB, OH, USA



MT 25
25th International Conference on Magnet Technology

August 27 – September 1, 2017

Contents

1. Introduction

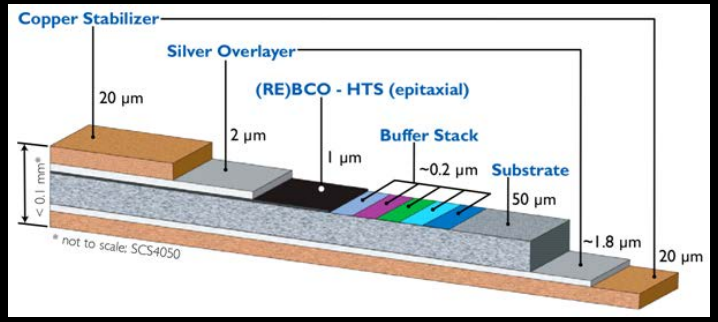
2. Bending of CORC cables
   - Experiments
   - Modeling (FEM)

3. Results

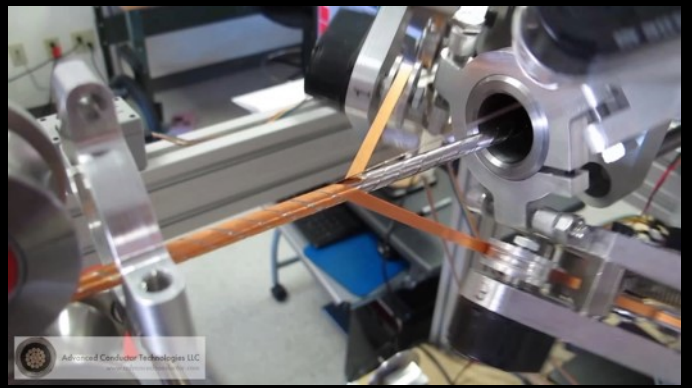
4. Conclusion

Introduction

- REBCO ($REB_2Cu_3O_{7-z}$) tapes
  - Excellent mechanical properties
  - Can carry very high current densities at very high magnetic fields (~ 20 T)
  - Can be operated at liquid N2 temperatures (77 K)
- CORC cables
  - Superconducting tapes wound on core
  - Very flexible
  - Very high currents and current densities
  - Mechanically very strong
  - Minimum degradation from cabling (< 10 %)
  - Current sharing between tapes possible



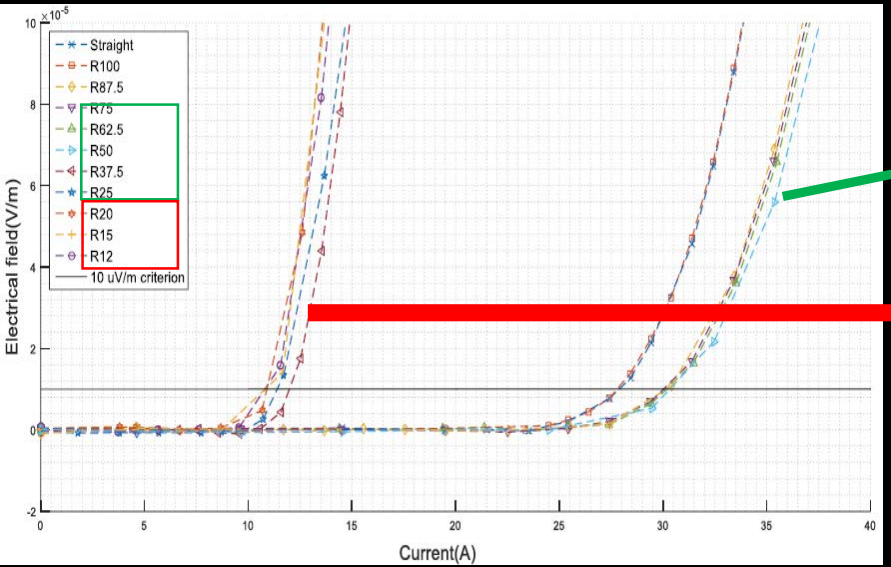
Individual tape configuration
based on SuperPower SCS x050 tapes

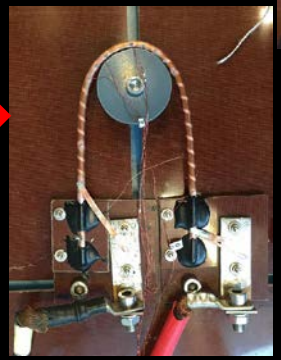


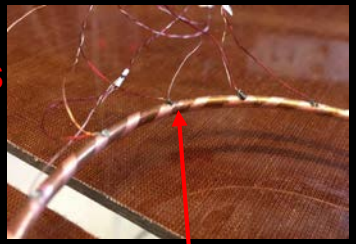
Bending of CORC cables

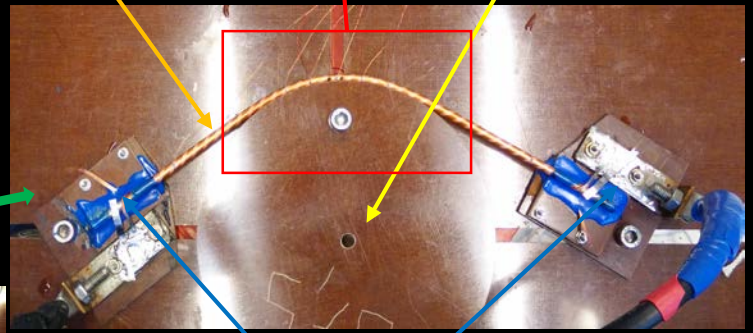
Experiment

- Samples are bend over a circular disc of variable diameters manually.
- Cooled down to 77 K in a custom made cryostat
- Electric field vs current behavior is recorded
- 10 µV/m criterion for I_c









Bending of CORC cables

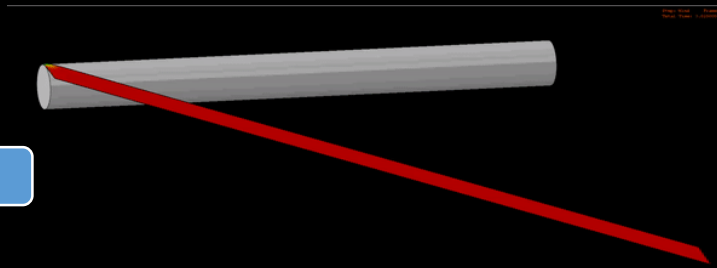
Experiment – Sample details

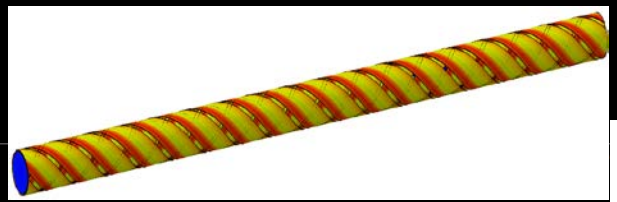
Id	Number of tapes	Core	Winding angle	Tape width	Lubrication	Number of samples measured
1	1	2.4	45	2.01	Unlubricated	3
2	1	2.4	30	2.01	Unlubricated	3
3	2	5.0	45	2.01	Unlubricated	4
4	1	5.0	30	2.01	Unlubricated	1
5	1	2.4	45	2.01	Lubricated	2
6	1	2.4	30	2.01	Lubricated	-
7	2	5.0	45	2.01	Lubricated	2
8	1	5.0	30	2.01	Lubricated	-
9	1	5.0	45	4	Solder coated	1 before HT 1 after HT
10	1	5.0	30	4	Solder coated	-

Bending of CORC cables

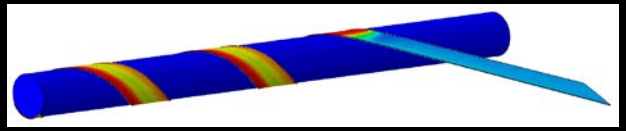
Modeling

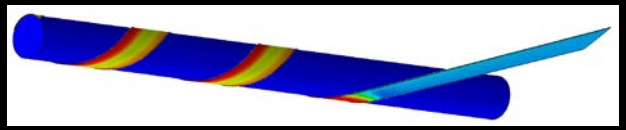
- Production process
- Winding different layers
- Stress-Strain transfer to full CORC geometry
- Bending

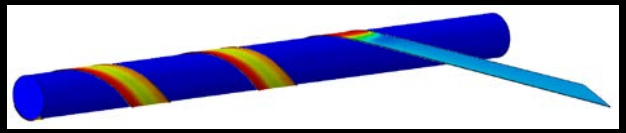


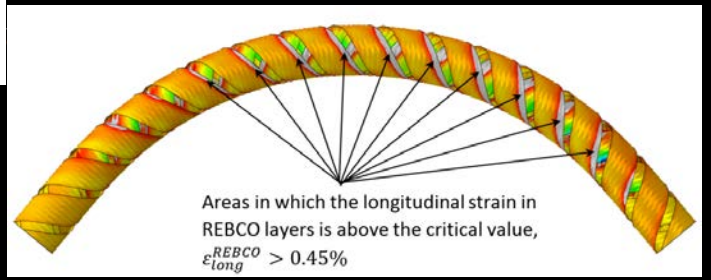


- Bending at room temperature
- Tape degradation at strain >0.45%



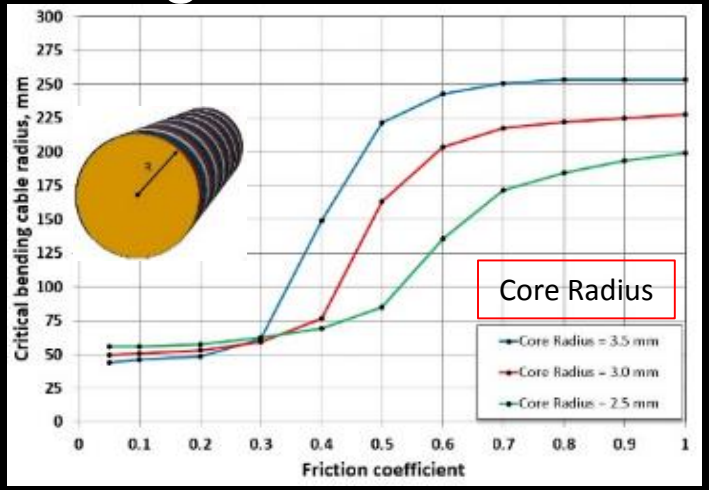


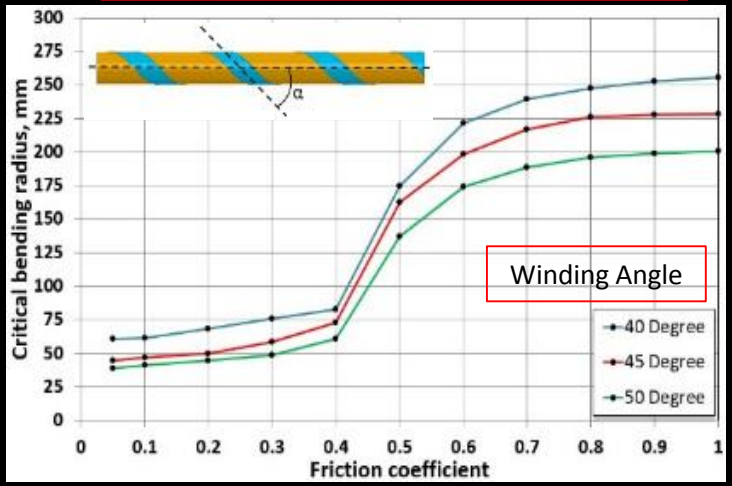


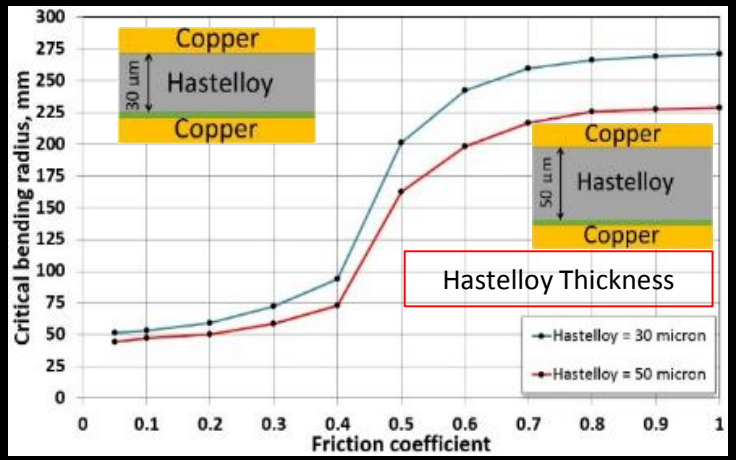


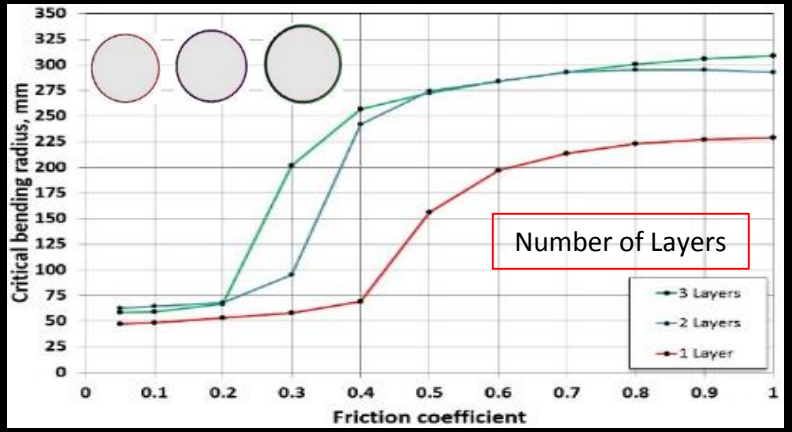
Bending of CORC cables

Modelling – Parametric study





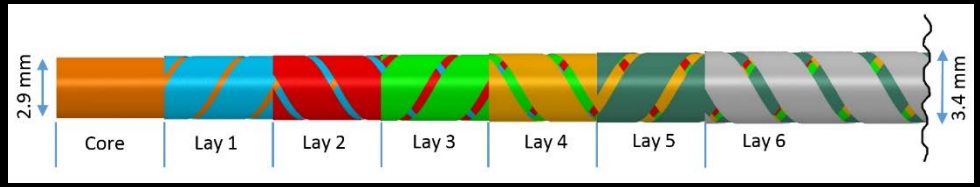




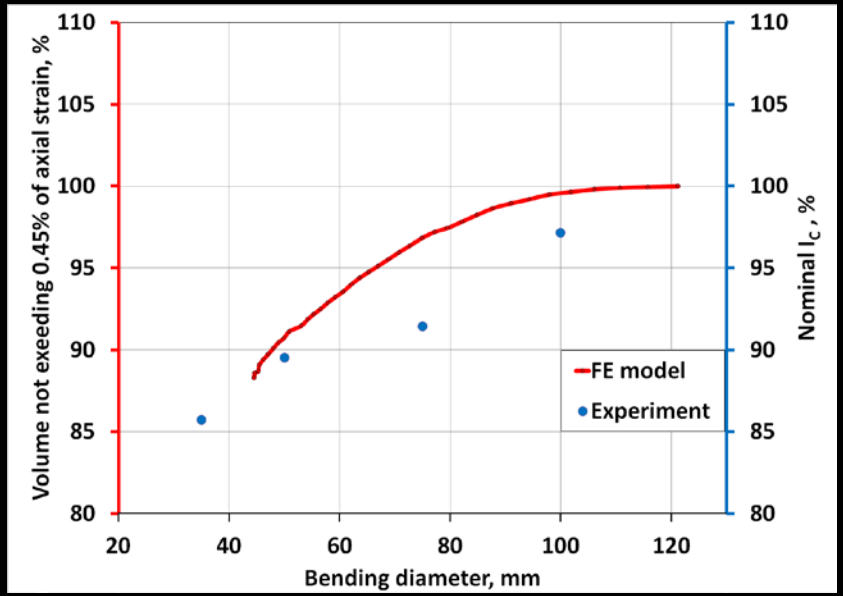
Verification FE model with experiment.

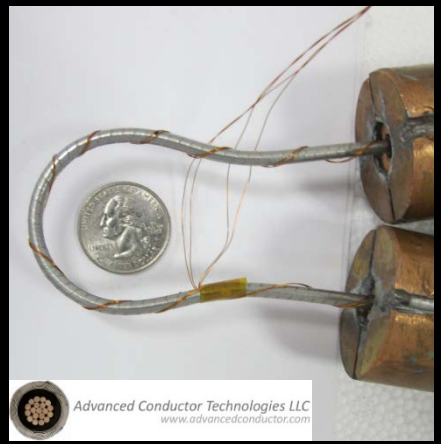
Cable configuration:

- 6 layers, 2 tapes per layer
- 2 mm wide tapes
- Total cable diameter: 3.4 mm
- Winding angle: 60^0
- Substrate thickness: 30 µm
- Copper plating: 5 µm



FEM model

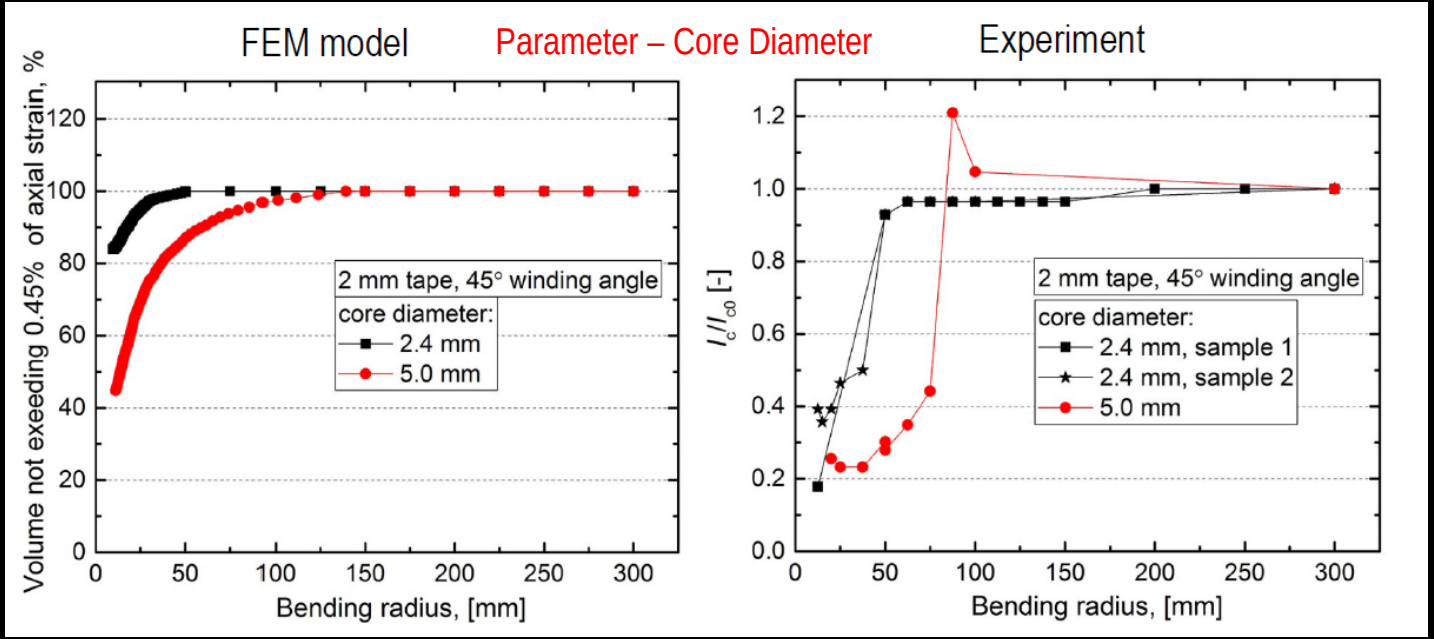




Experiment

Results

Bending one layer CORC cable

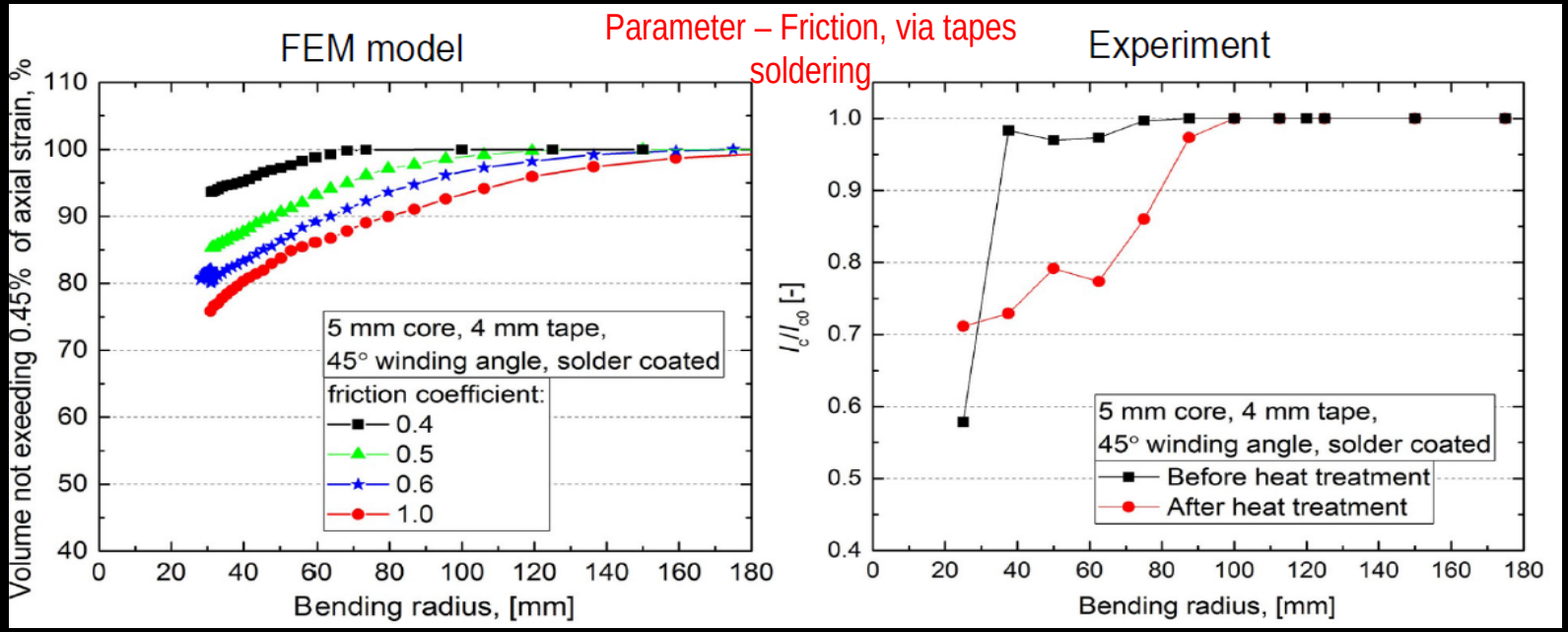


Friction coefficient is fixed to 0.6. Qualitatively good agreement with experimental data.

Samples with 2.4 mm core start to degrade at 50 mm bending radius. Samples with 5 mm core start to degrade at 80 mm bending radius.

Results

Bending one layer CORC cable

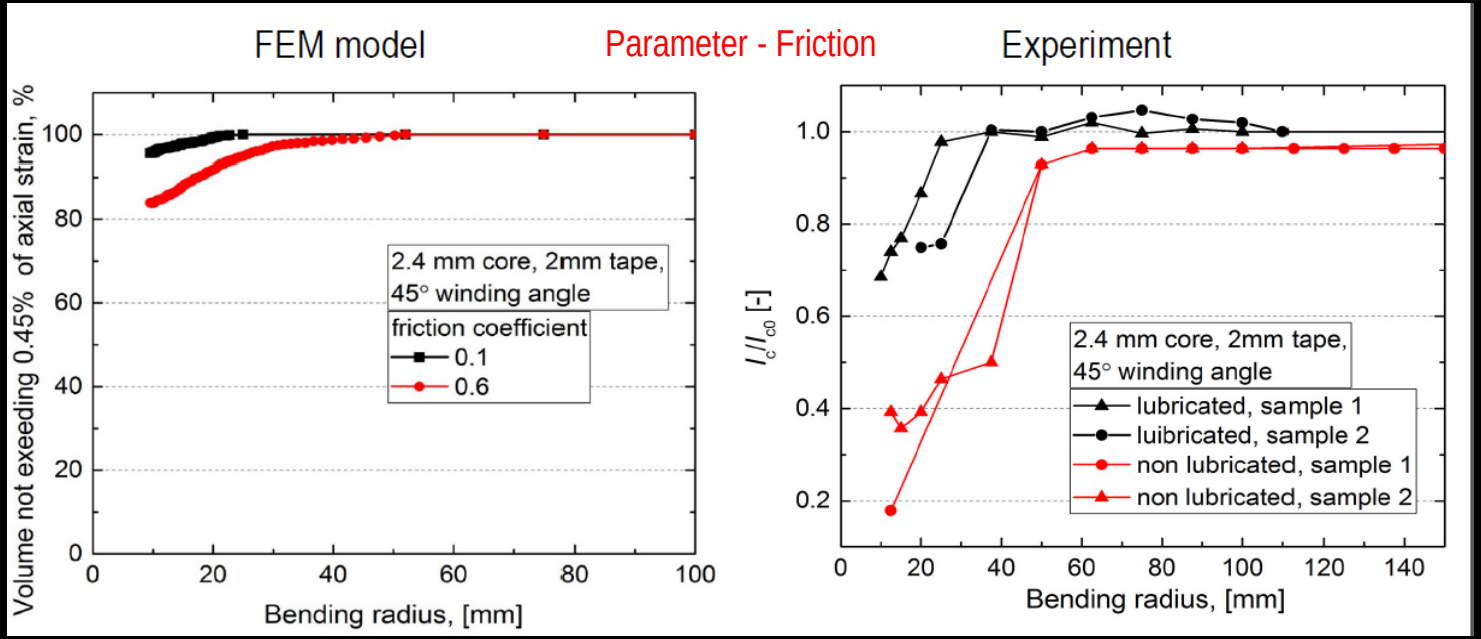


Non soldered cable modelled with 0.4, 0.5 and 0.6 friction coefficient. For soldered conductor friction coefficient 1.0 is taken.

By tapes soldering to the core friction coefficient 1.0 is simulated. Early degradation is observed for soldered conductor.

Results

Bending one layer CORC cable

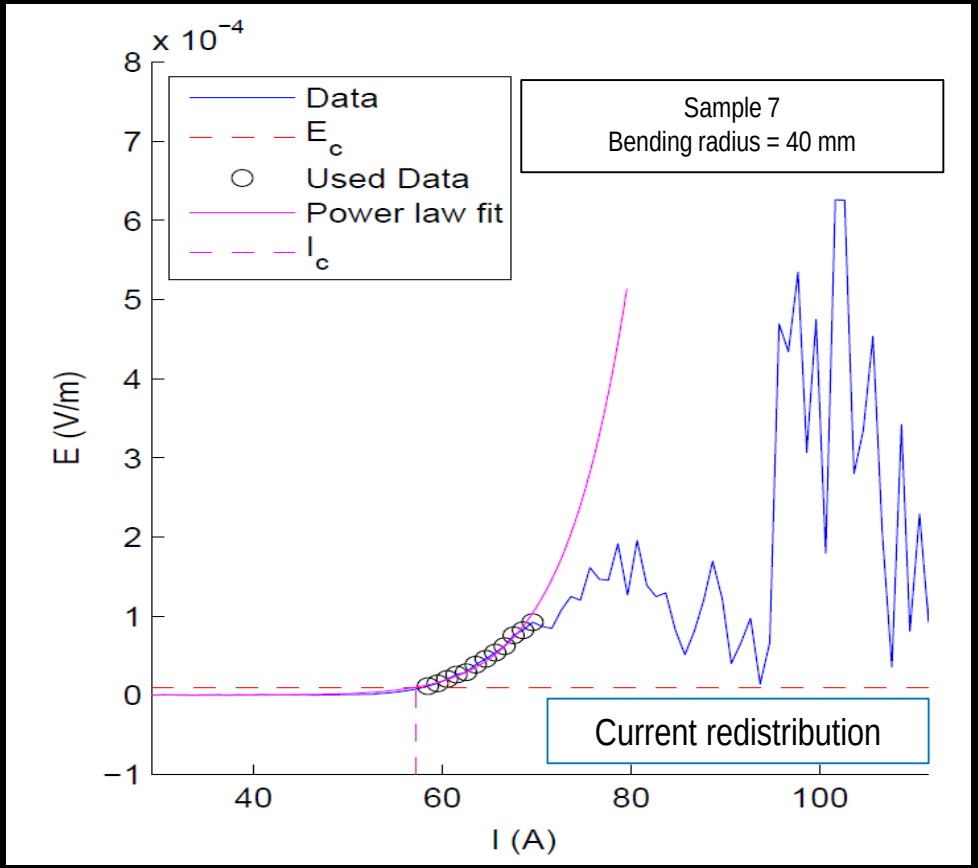


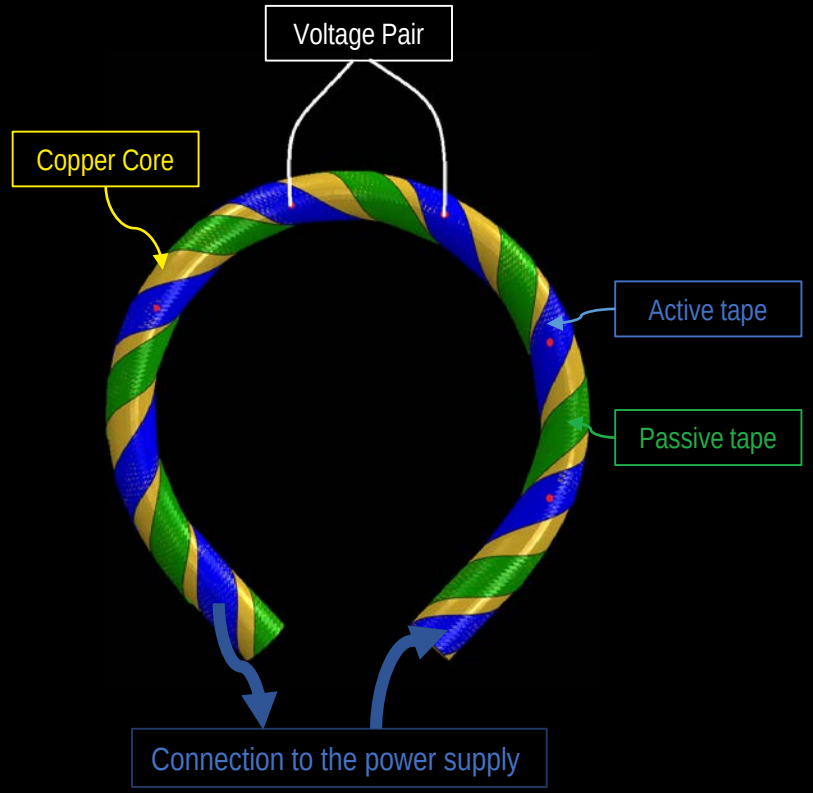
A good agreement with experiment achieved for friction coefficients 0.1 and 0.6.

Lubricated sample shows Ic degradation at 25 mm bending radius. Non lubricated sample shows Ic degradation at 50 mm bending radius.

Results

Current transfer effect





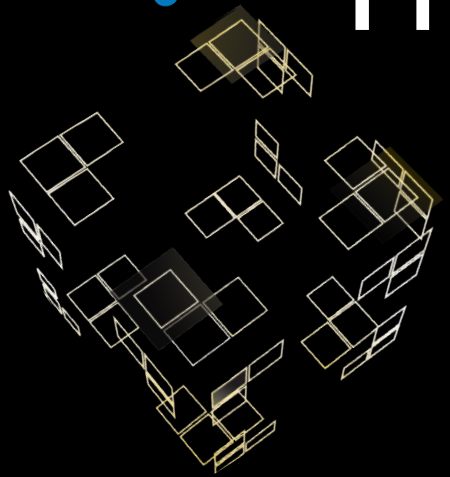
Current shared between active and passive tapes at higher current (at low bending radii)

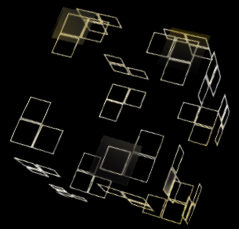
Conclusion

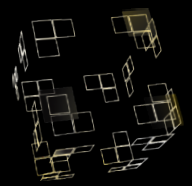
- Tape FE model build and validated against experiments.
- CORC cable FE model developed based on validated tape model.
- CORC model predictions largely in agreement with experiments.
- Optimal CORC cable design by model is possible, depending on the type of load (bending, cooling, Lorenz forces etc.).

UNIVERSITY
OF TWENTE.

Thank you!







UOW AUSTRALIA

Advanced Conductor Technologies LLC
www.advancedconductor.com

AIR FORCE RESEARCH LABORATORY

EMS