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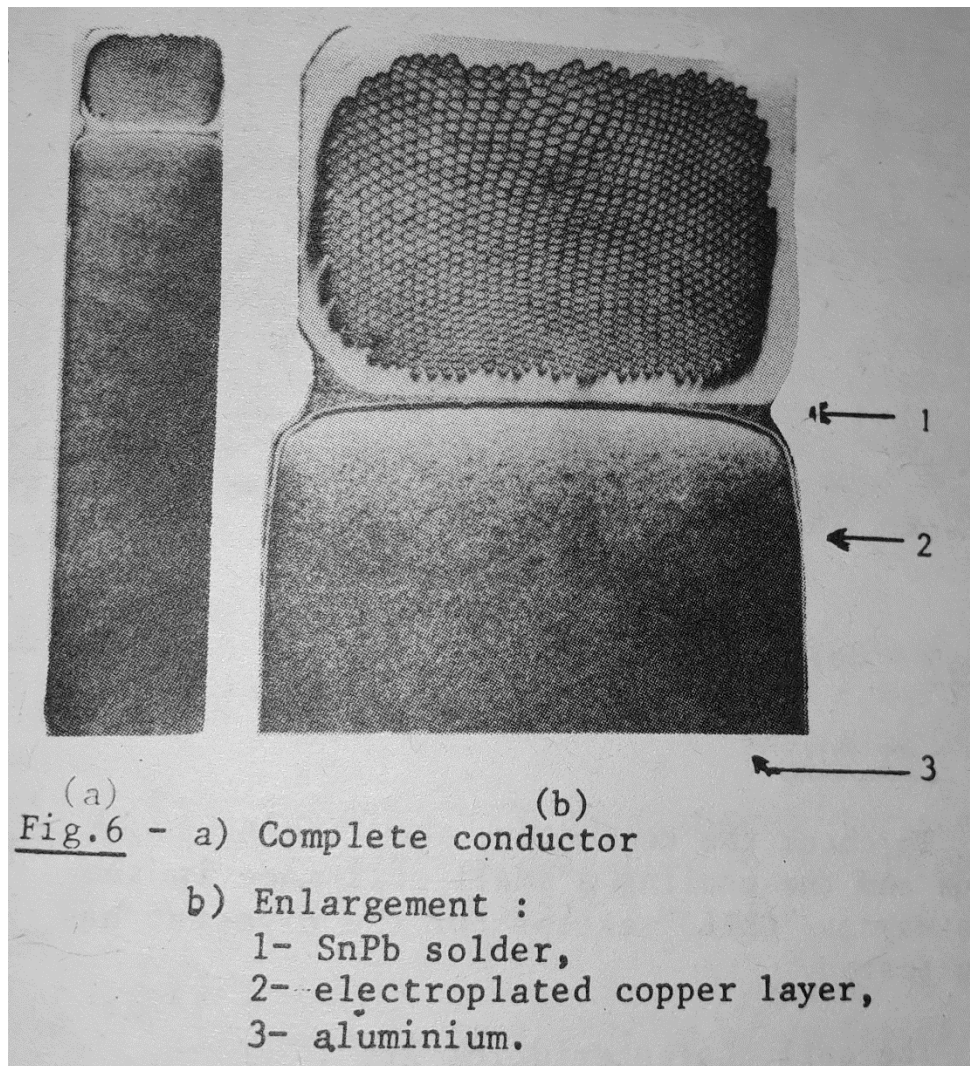
Soldered Aluminum conductor: A backup solution?

Saclay experience

Christophe Berriaud

It was 20 years ago

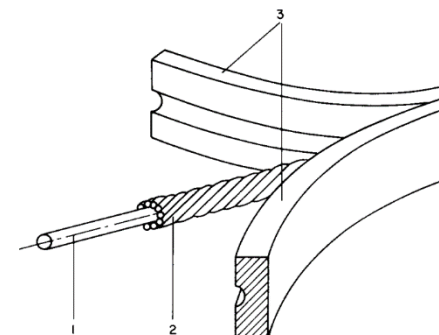
- Historical: old work done at Saclay
- General consideration
- Conclusions

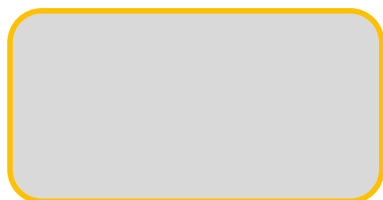


Cello Conductor

One of the first aluminum soldered conductor 1979 for a solenoid of 1.5 T ($\varnothing_i = 1.6$ m, length 4 m).

One year after Morpurgo magnet

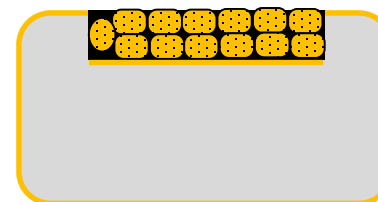




Existing Al.
stabilizer with
copper deposition

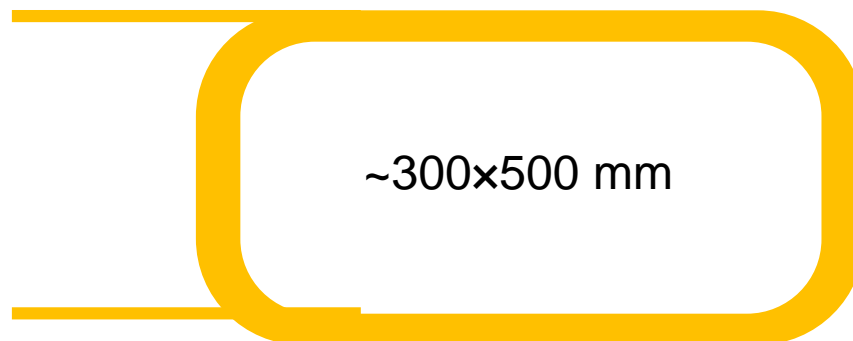


Groove
machined by
Turck head



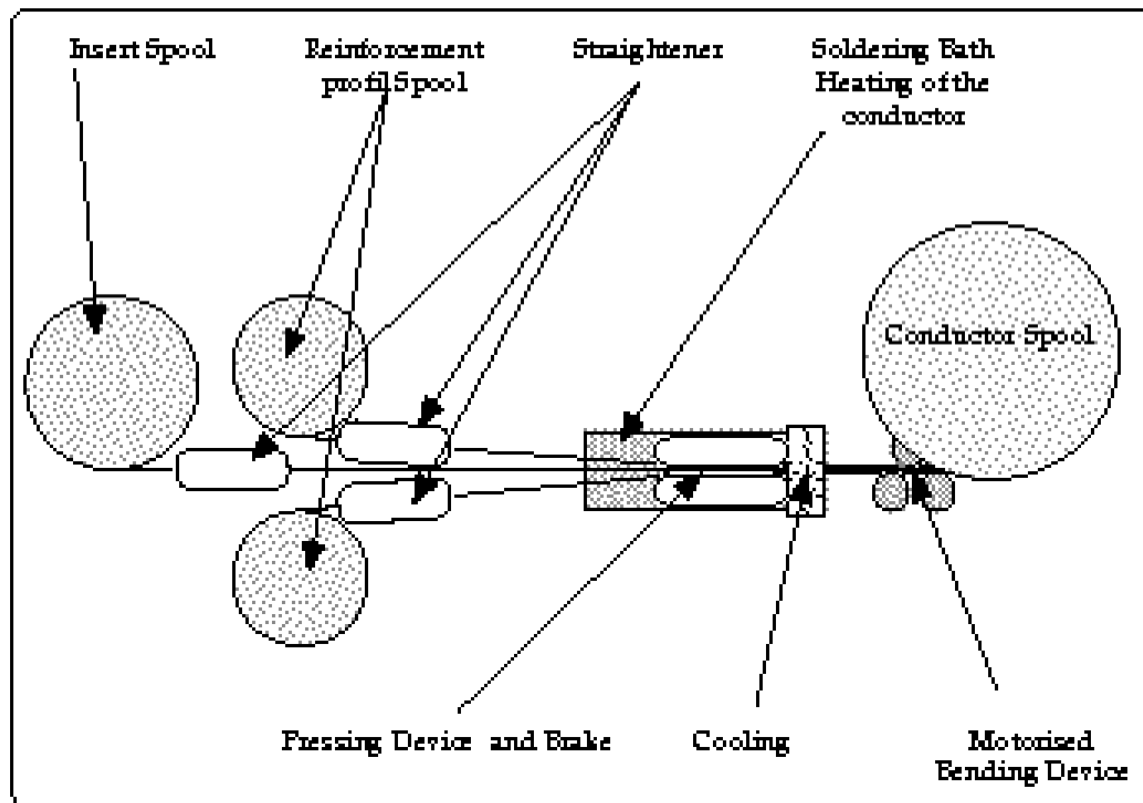
Existing Rutherford
& soldering by
hand

~2x5 mm



First ATLAS Racetrack (MicroB)

Quench studies
& inductive heater



Principe of the reinforcement soldering line of CMS
(Back up solution)

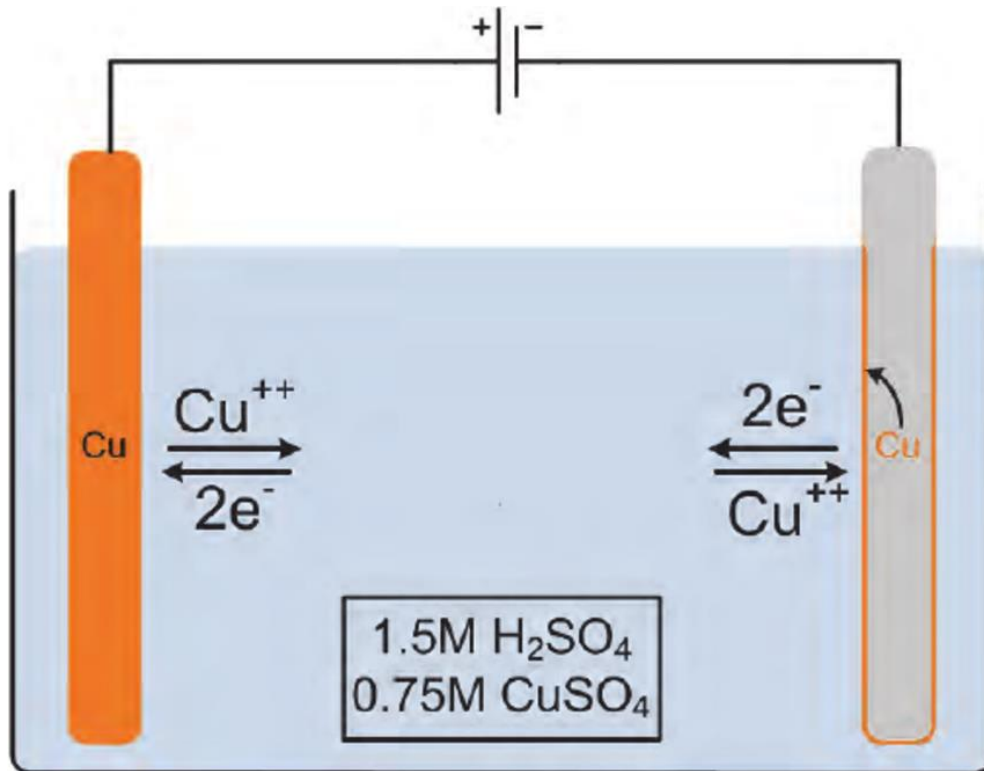
Electrolytic copper deposition was made by PEM (F).

Reinforcement the has been solder by hand at Saclay: old geometry $(5+5)*70$ mm².

Cream solder with flux has been tested; but number of bubbles (due to the flux) were trapped between pieces.

Wave solder, Ultra sonic solder bath and vertical position would improve the soldering process by removing most of bubbles.

Temperatures (including gradient) and time must be set carefully.



Standard copper electrodeposition

To make a good electrolytic copper deposition on aluminum you need to remove the Al_2O_3 oxidation of the external surface of your piece.

As Al. oxidation get very fast in air, the usual solution is to use one bath with the etching of Al. and the Cu^{2+} cation together in solution.

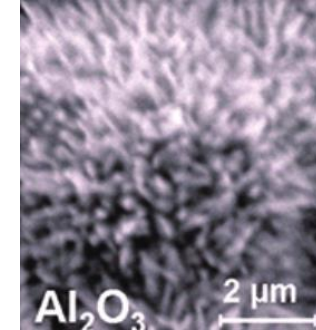
It takes TIME!



Deposit locally by tampon

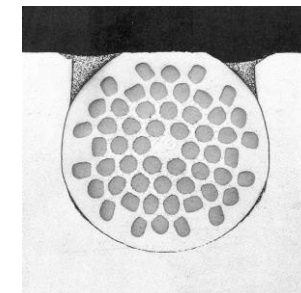
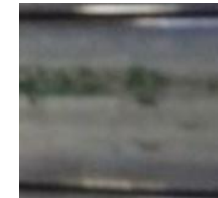
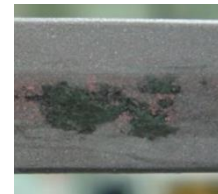
Electrodeposition:

- One, we get Al_2O_3 filaments up to 2 cm due to material (toxic) use in the flux and the presence of humidity...



Soft soldering:

- Presence of flux in the remaining bubbles.
- Large possibility of oxidation: black spot, yellow, green, white ...
- Local backup solution is need in case of lake of soldering.
- “Poor” bonding quality ($\sim 25 \text{ MPa}$) but not so different than pure Al. Thermal contraction Al./Cu gives already 10 MPa.



Crimped Wire In Channel

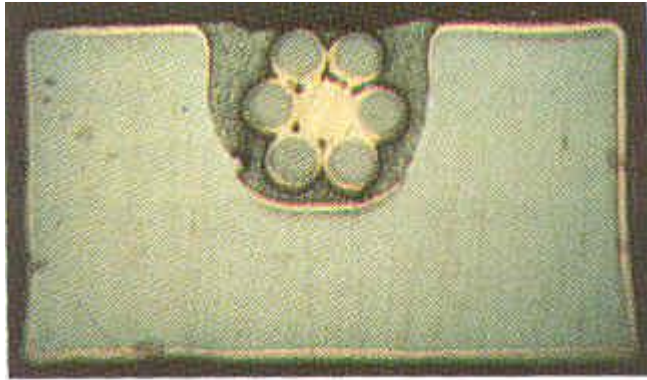


Commercial copper clad wire

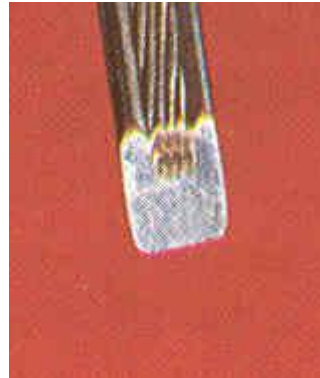
An alternative more industrial method is to place a copper tube around aluminum cylinder and to draw the overall. With a large section reduction the oxidation is diluted on the wire surface and good bonding is obtained.

Cladding process can also be continuous: welding tube around wire.

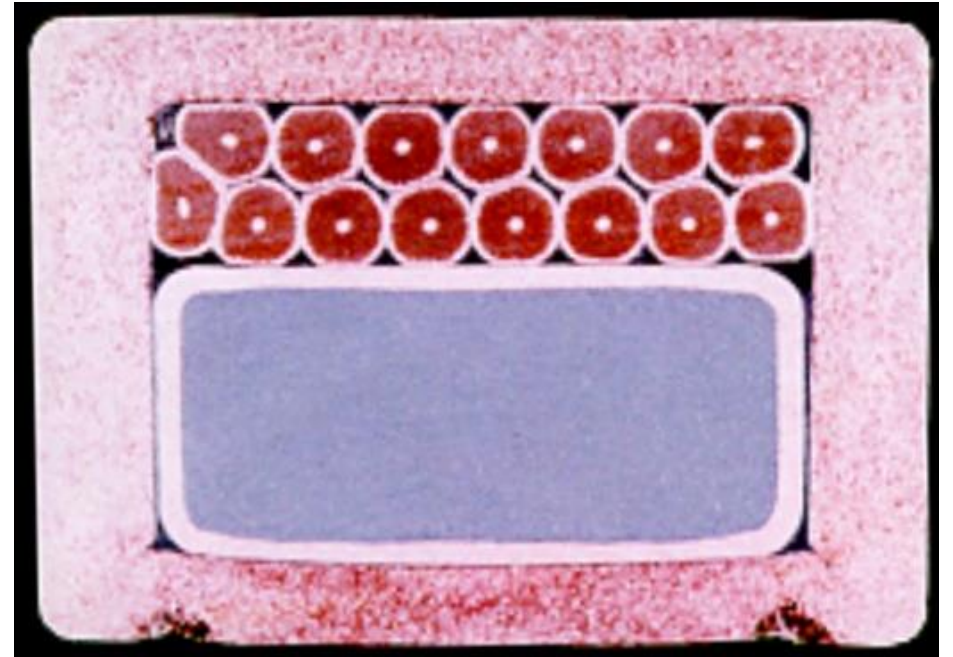
CONDUCTOR EXAMPLES



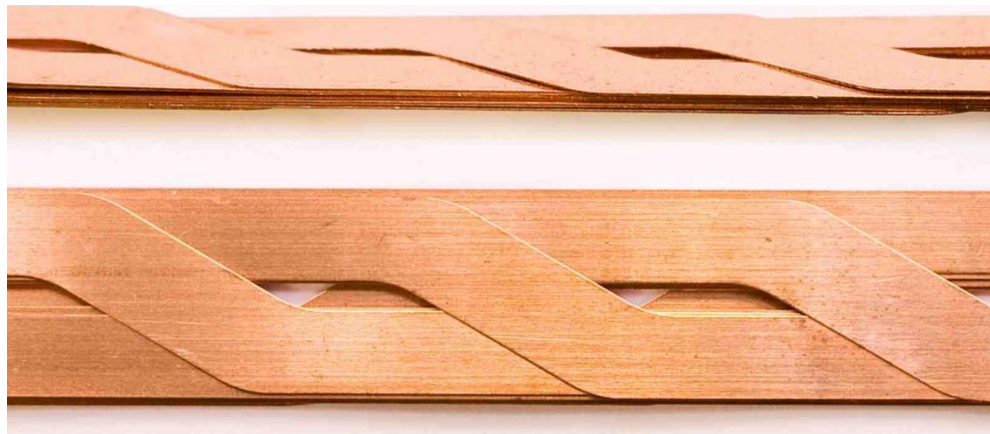
6+1 in Channel
(Not crimping!)



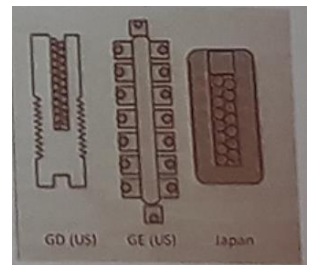
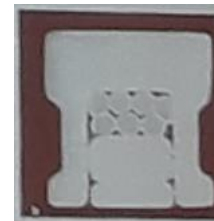
Cu deposit or
direct
soldering?



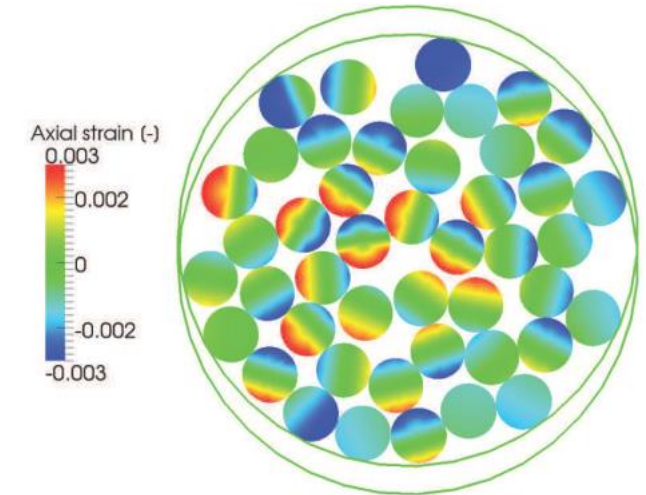
HLD conductor
(CuNi2% clad)



HTS !



- Cu electrodeposition is possible but quite expensive.
- Clad coating is an alternative (more copper).
- Do we need soldering? We need:
 - Mechanical support.
 - Electrical and thermal contact.



Transverse cross-section of a cable submitted to 50 kN/m transverse compression.

Numerical simulation of the mechanical behavior of the ITER cable-in-conduit conductors,
Hugues Bajas



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