The brittle intermetallic Nb₃Sn superconductor is currently being used to develop high field magnets in the framework of the Hi-Luminosity upgrade of the Large Hadron Collider at CERN. Despite its excellent superconductive properties, Nb₃Sn wires suffer from significant critical current $I_c$ reduction due to the transverse load applied during the magnets’ assembly and energization. In high critical current density $J_c$ RRP and PIT wires ($J_c > 1200$ A/mm² at 15 T, 4.2 K), the $I_c$ is reduced by about 20% at 12 T (and 40% at 19 T) when applying a transverse load of 150 MPa because of the strain state on the superconductor.

A dedicated FEM 3D numerical model coupled with a $J_c$ scaling law has been developed to predict the electro-mechanical behaviour of RRP and PIT wires under transverse loads. By using this model, the effects of different geometrical factors have been studied to identify the key parameters that allow limiting the effect of transverse loads on the $I_c$ reduction under transverse load. In particular, this poster deals with the role of the: production technologies, diameter, sub-elements layout, heat treatment and precompression.

Full detailed 3D geometry of the strand (no homogenization).
- Mechanical simulation to obtain deformed geometry after 15% flat rolling, to mimic the deformation due to the cabling operations.
- Only the deformed geometry has been transferred to the electro-mechanical model (residual strain after reaction were considered negligible).
- A variety of strand layout has been investigated:

**Model setup**

- **Elastoplastic material model for copper stabilizer.**
- **Orthotropic elastic model for the SC filaments.**
- **Solid Bronze in the RRP cores**, no material in the PIT cores (resistance of the porous Nb-Sn intermetallic reaction residual is considered negligible).

Comparison between FEM calculated geometry and cross section of a 0.85 mm PIT 192 strand with bundle barrier.

- Details of the deformed filaments:

### Strain function calculation

\[ \varepsilon(l) = \frac{1}{2} \left( \varepsilon_l(l) \right)^2 \]

- FEM mechanical model coupled with $J_c$ exponential scaling law by Bordini et al.
- Precompression added during data post-processing

### Influence of $B_{c20}$ and applied field

- The model can predict the influence of both the externally applied field and the conductor $B_{c20}$ on the $I_c$ reduction.
- At 12 T the reduction is relatively low, since the $B_{c20}$ reduction plays a smaller role being the applied field far from the critical level.

### Influence of the production technology

- Relevant influence of the bronze core within the sub-elements on the reduced strain sensitivity of RRP compared to PIT.
- When the bronze core is removed from the RRP strand the simulation data show higher $I_c$ reduction, in line with the PIT case studies.

### Conclusions

- This poster presented an overview of the effects of different geometrical and technological parameters on the critical current reduction of Nb₃Sn strands under transverse pressure.
- Comparative analyses have been carried out on a 3D FEM model to highlight the contribution of different parameters on the overall critical current reduction.
- The lower strain sensitivity of RRP wires with respect to PIT strands has been linked with the reinforcing effect of the bronze cores within the sub-elements.
- The model has shown the relevant effect of copper plasticization on permanent $I_c$ reduction after unloading.
- The obtained results show the potentials of the proposed modelization strategy to simulate and predict the behaviour of superconductors under transverse pressure.