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Study on Jacket Performance and CRAFT TF Coil Heat Treatment

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ABSTRACT

- **Modified 316LN and JK2LB stainless steel** were selected as candidate jacket materials for superconducting cable in conduit conductors (CICC) of the China Fusion Engineering Test Reactor (CFEDR).
- The mechanical properties of materials were measured **at 4.2 K, 77 K and 300 K**, and yield strength, ultimate tensile strength and elongation at failure were reported.
- To evaluate the final mechanical properties of CICC conductors wound into coils under actual service conditions, **heat treatment was performed on CRAFT TF coils**.

BACKGROUND

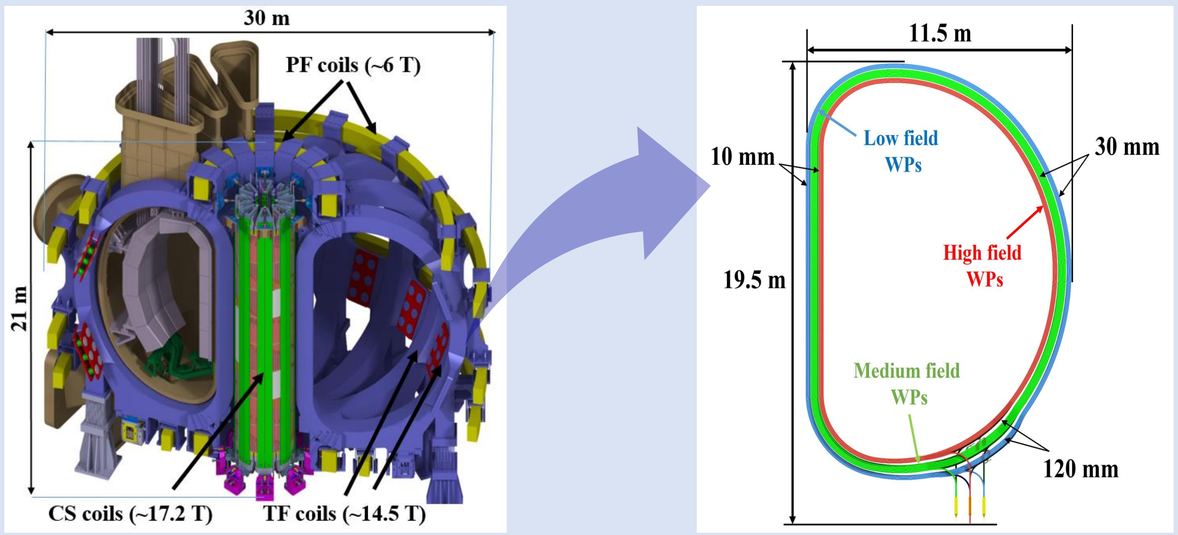

Fig. 1 left: Main components of the CFEDR magnet system; Right: The dimensions of the CRAFT TF coil winding.

- The magnet system is the core component of Tokamak, mainly including **central solenoid (CS) coils, toroidal field (TF) coils and poloidal field (PF) coils**. The Comprehensive Research Facility for Fusion Technology (CRAFT) project was officially initiated to conduct pre-studies of the China Fusion Engineering Demo Reactor (CTEDR) **prototype components and systems**.
- All coils of the superconducting Tokamak are designed with different sizes of **Cable-In-Conduit Conductors (CICC)** and will be cooled by forced flow of supercritical helium.
- The mechanical properties of **modified 316LN and JK2LB materials** under the variation of cold working conditions, four different annealing conditions and three different test temperatures were investigated .
- The conductor material used for the CRAFT TF coil is modified 316LN, with a cross-sectional dimension **of 64 mm × 64 mm**. **The heat treatment results and contour deformation** of the CRAFT TF coil were demonstrated.

SPECIMEN PREPARATION AND TEST PROCEDURES

Table 1. The jacket dimensions.

Identification	Cold working deformation
CW0	0%
CW5	5.1%
CW9	9.2%

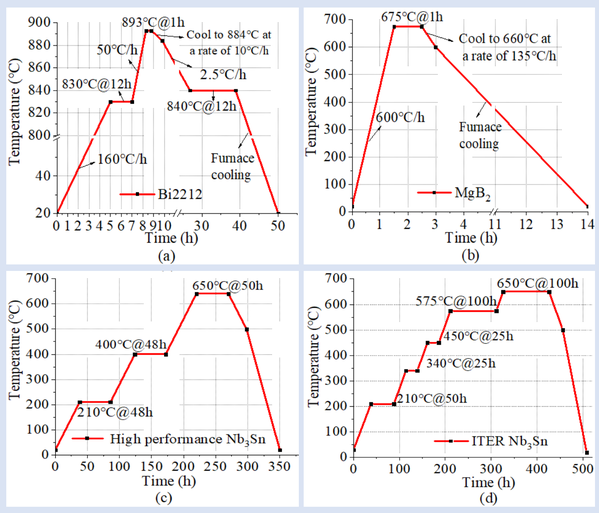

Fig. 2. Four heat treatment regimes (a: Bi-2212; b: MgB_2 ; c: high-performance Nb_3Sn; d: ITER Nb_3Sn).

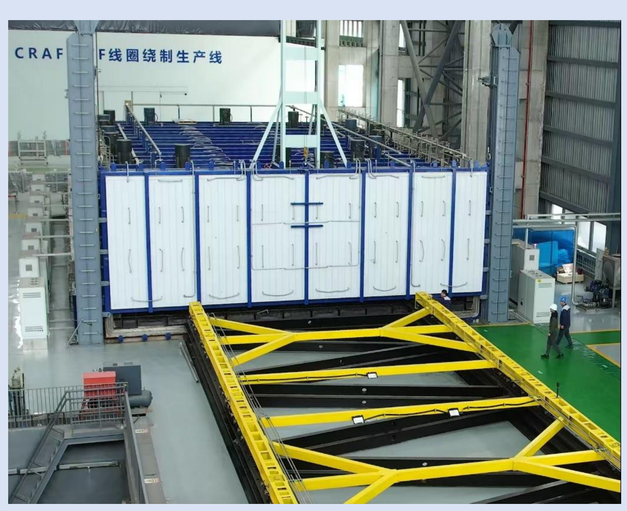

Fig. 3. The picture of CRAFT TF heat treatment system.

RESULT

1. Mechanical Properties of Modified 316LN and JK2LB

- All JK2LB and modified 316LN samples with a cold working deformation of 5.1% (actual deformation of CSMC conductor manufacturing) have a **yield strength >1050 MPa and elongation >40% under 4.2 K test conditions.**

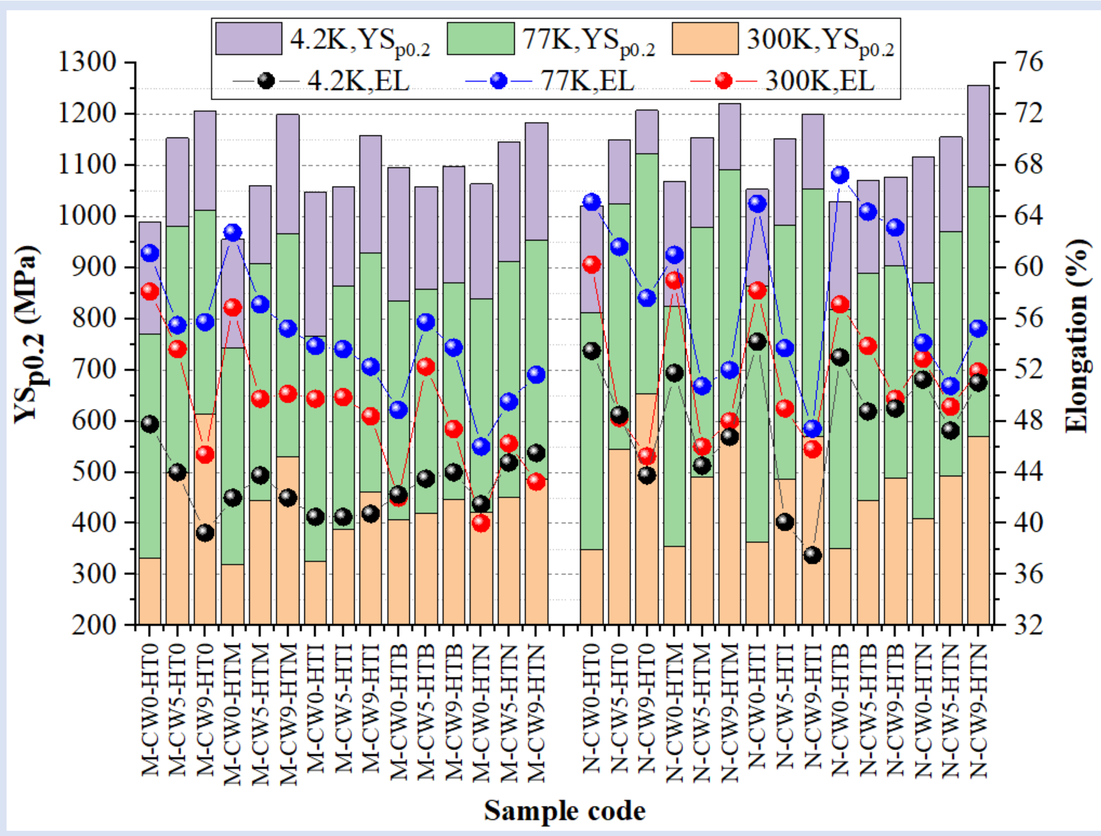

Fig. 4. The yield strength and elongation of samples.

2. TF Coil Heat Treatment

- During the critical plateau at 650 ℃ on the heat preservation platform, **the temperature uniformity remained within ± 5 ℃,** meeting the specified requirements.
- The deformation of the high-field and medium-field coils before and after heat treatment is **less than ± 1 mm**.

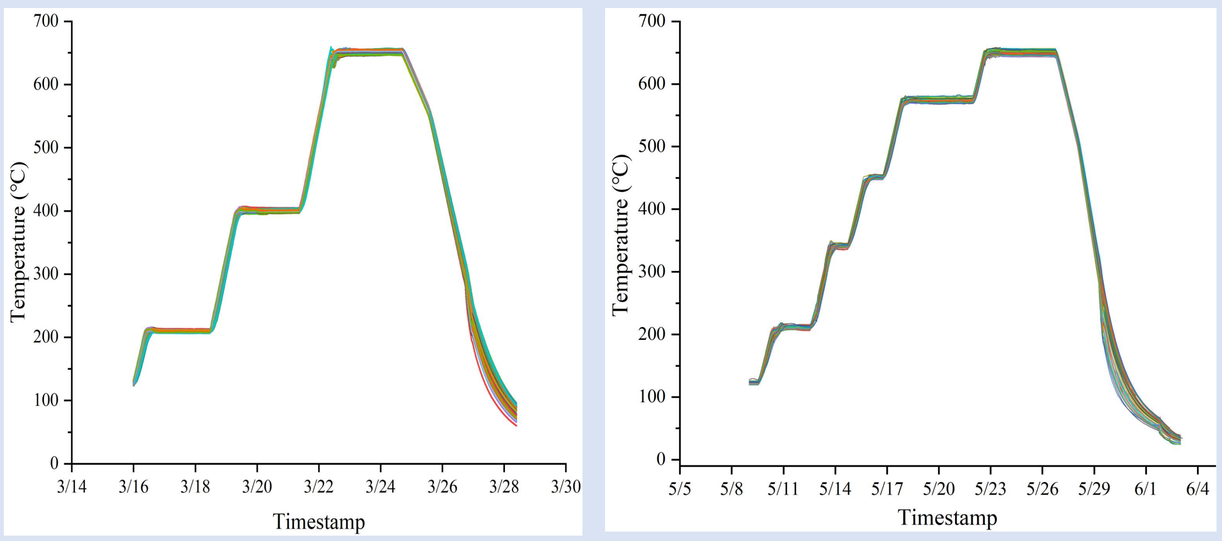

Fig. 5. Left: TF high-field coil; Right: TF medium-field coil.

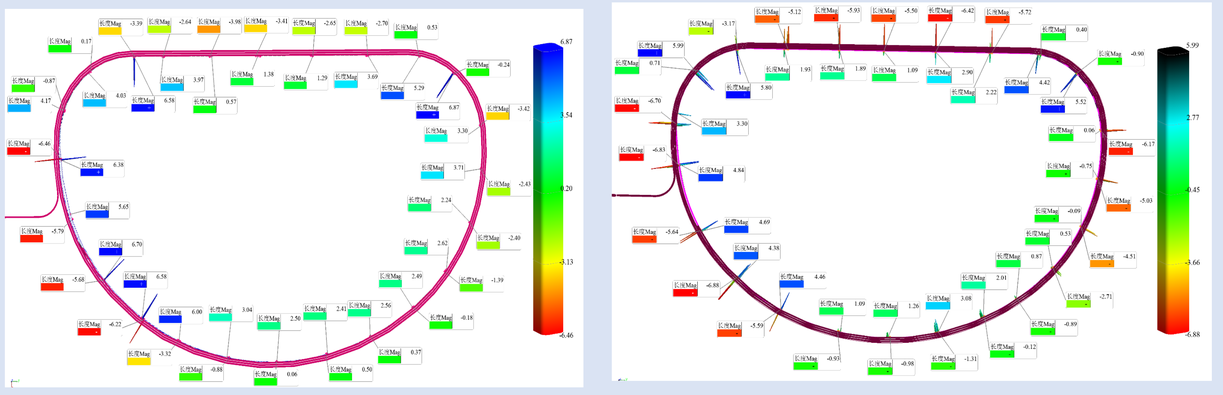

Fig. 6. High-field coil (Left: Before heat treatment; Right: After heat treatment).

CONCLUSION

- The test results show that the JK2LB and modified 316LN jackets after cold working and aging have a yield strength >1050 MPa and elongation >30% at 4.2 K.
- Modified 316LN produced in China have been successfully applied in CRAFT TF coils. Currently, and the heat treatment experimental outcomes of the TF coils have shown promising results.