Contribution ID: **844** Type: **Contributed Oral**

Sat-Mo-Or1-03: Long-Term Performance of Pultruded Fiberglass Pre-Compression Rings for ITER

Saturday 5 July 2025 09:00 (15 minutes)

The ITER Pre-Compression Ring system provides radial constraint and centripetal load to the 18 TF coils. The rings are composed of six pultruded fiberglass-reinforced composite rings with an external diameter of 5.6 m, a cross-sectional area of 95,600 mm², and a weight of 3.4 tons each. These rings are designed to operate at 4.2 K during 20 years under preload given at room temperature during their assembly.

To investigate how prolonged loading affects key mechanical properties, such as ultimate tensile strength (UTS) and ultimate compressive strength (UCS), an extensive 3-year test program included tests on both small-scale specimens and 1/5-scale PCR mock-ups. Full-scale tests under operational conditions would have been prohibitively expensive and difficult to implement, so small-scale specimens were used to study the material's creep behavior under tensile and compression loads for up to 5000 hours at room temperature. This approach allowed for testing a large number of samples to provide statistical confidence in the results. The small-scale tests were performed by CERN, Switzerland.

In parallel, eight 1/5-scale PCR mock-ups with a diameter of 1 m were tested at ENEA Frascati. The test campaign included stress relaxation tests at different stress levels and durations, followed by UTS tests at room temperature. To replicate operational conditions more accurately, one mock-up was subjected to an uneven load distribution to simulate the pre-compression effects experienced by the full-size rings. Another mock-up was tested with an artificial defect to evaluate the impact of structural imperfections on mechanical performance.

Finite element method analysis was conducted to support the experimental campaign. The analysis was used to translate the preload conditions of the full-size rings to the 1/5-scale mock-ups. This approach ensured that the test conditions for the subsize rings accurately reflected the behavior expected in full-size rings.

The combined results from the tests revealed that stress relaxation does not influence the mechanical properties of the rings. These findings validate the design, material selection, and manufacturing process of the PCRs. The study concludes that the pultruded fiberglass-reinforced composite rings can maintain their mechanical performance and structural reliability throughout the entire 20-year operational life of the ITER tokamak. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Session Classification: Sat-Mo-Or1 - Assembly and Commissioning Fusion Tokamaks