Evaluation of the cryogenic mechanical properties of the insulation material for ITER Feeder superconducting joint

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Abstract

The glass-fiber reinforced plastic (GFRP) fabricated by the vacuum bag process was selected as the high voltage electrical insulation and mechanical support for the superconducting joints and the current leads of ITER Feeder system. To evaluate the cryogenic mechanical properties of the GFRP, the mechanical properties of the GFRP were measured at 77K in this study. The results demonstrated that the GFRP met the design requirements of ITER.

Introduction

In ITER feeder system, hundreds of superconducting joints are used to assemble the segments of the superconducting busbars and to connect the busbars to the coil terminals. In general, the GFRP was selected as the insulation material and mechanical support material for the superconducting joints. During operational conditions, the joint insulation sustains the stress from the large temperature gradient, the long term thermal cycle and the high electromagnetic force. To ensure the system reliability and performance, ITER established several acceptance criteria and expectations for the mechanical properties of the joint insulation and support material, including 77K static ultimate tensile strength (UTS) > 500 MPa, interlaminar shear strength (ILSS) > 60 MPa, and residual UTS > 200 MPa after 30,000 cycles load. To evaluate the reliable application of GFRPs, their mechanical performance were characterized under static and dynamic load conditions at 77K in this study.

Sample preparation

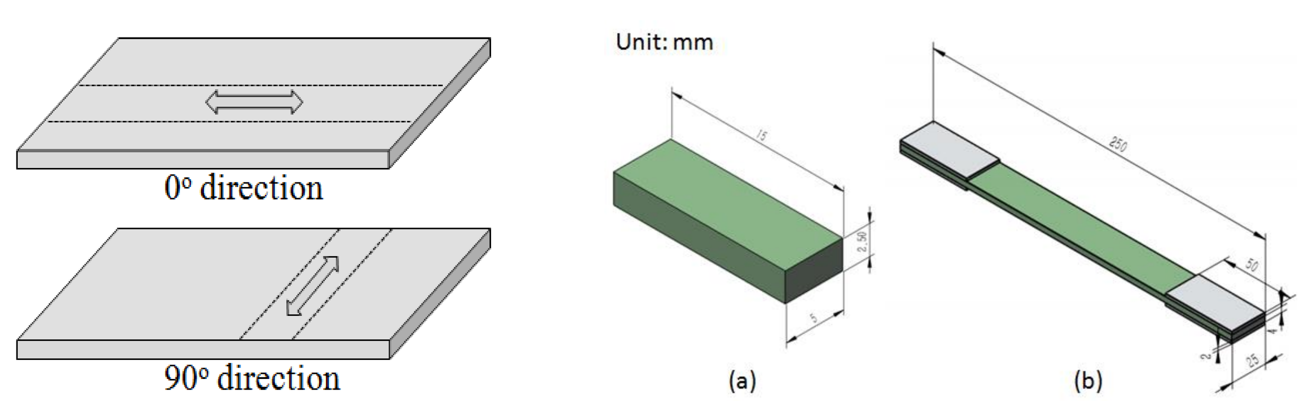
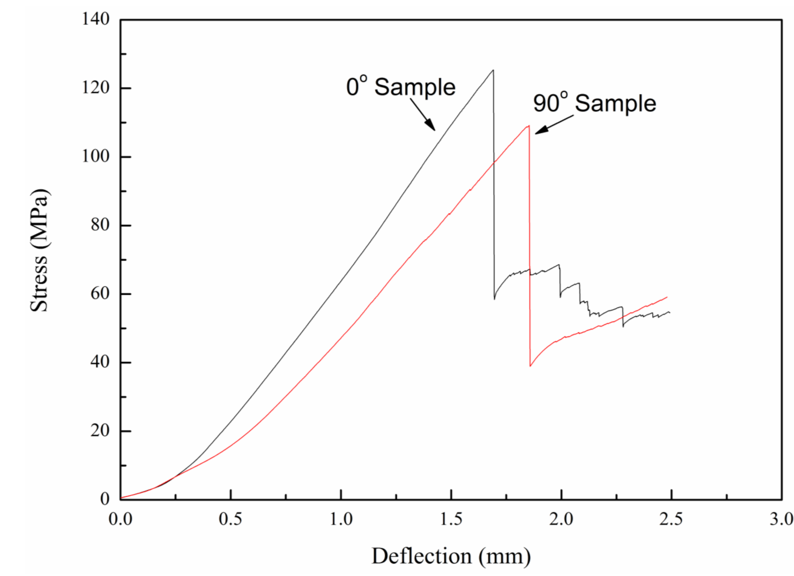


Figure 1. Schematic diagram of the sample for SBS (a), tensile (b) and fatigue tests (b).

ILSS Test

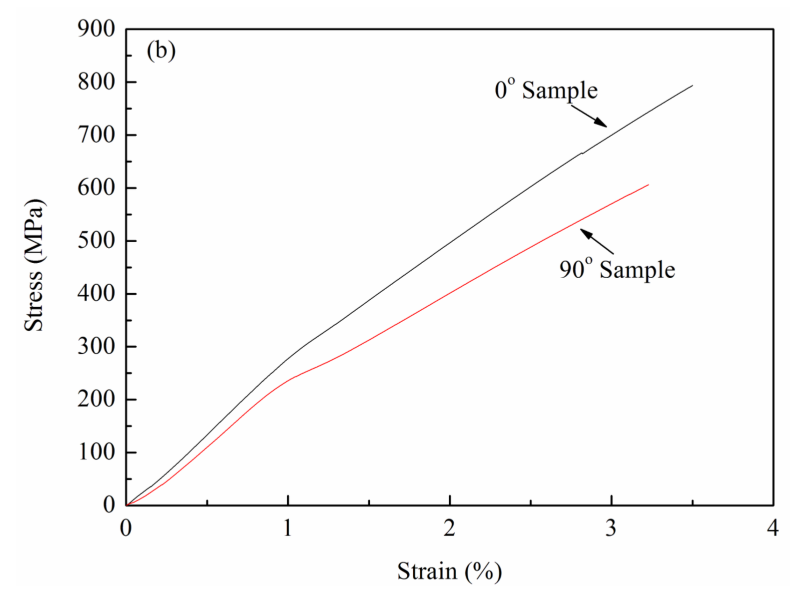


	ILSS (MPa)	
	0° direction	90° direction
1	126.6	106.7
2	125.4	98.8
3	124.6	109.2
4	124.9	104.7
5	123.5	100.5
Mean value	125.0±1.1	104.0±4.3
ITER Requirement	60	60

Figure 2. ILSS test curves of 0° sample and 90° sample

- The fracture mode of all tested samples was interlaminar shear fracture.
- All tested samples meet the ITER requirement for the ILSS > 60 MPa.

UTS Test



	UTS (MPa)	
	0° direction	90° direction
1	711	638
2	770	606
3	801	665
4	719	685
5	794	595
Mean value	759±41.9	638±38.1
ITER Requirement	500	500

Figure 3. UTS test curves of 0° sample and 90° sample

- The slope of the stress–strain curve changed abruptly, presenting a knee behavior.
- All test results are higher than 500 MPa which was required by ITER.

Fatigue Test

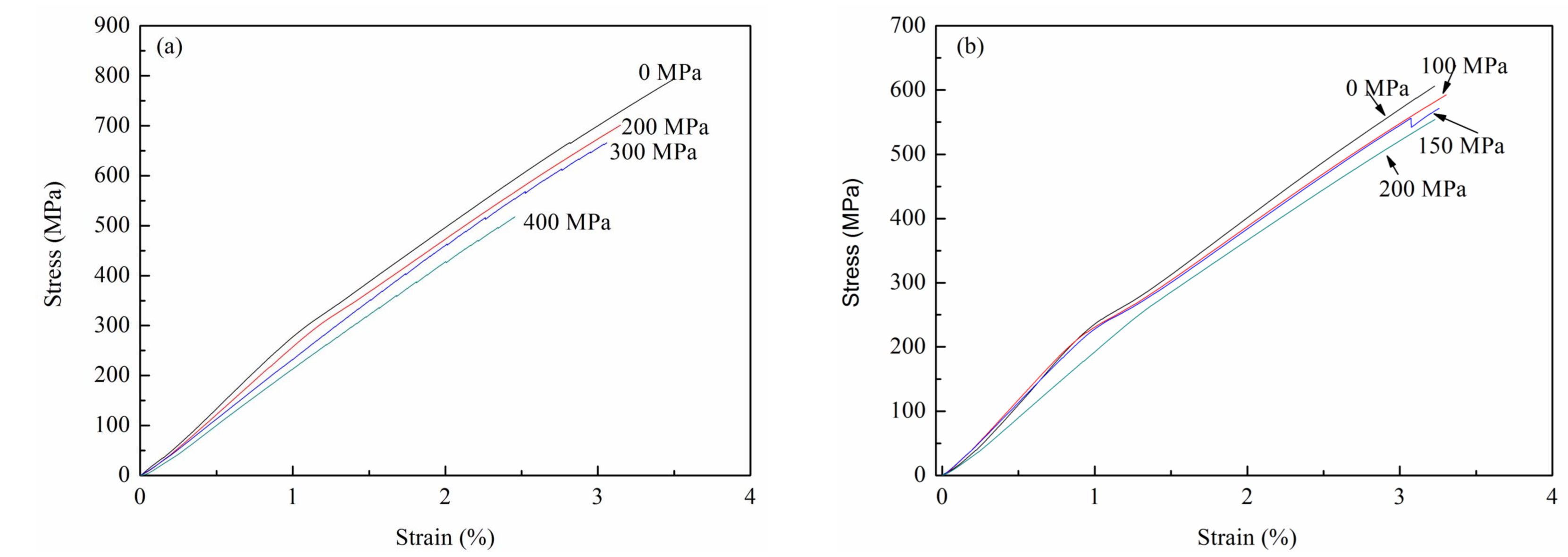
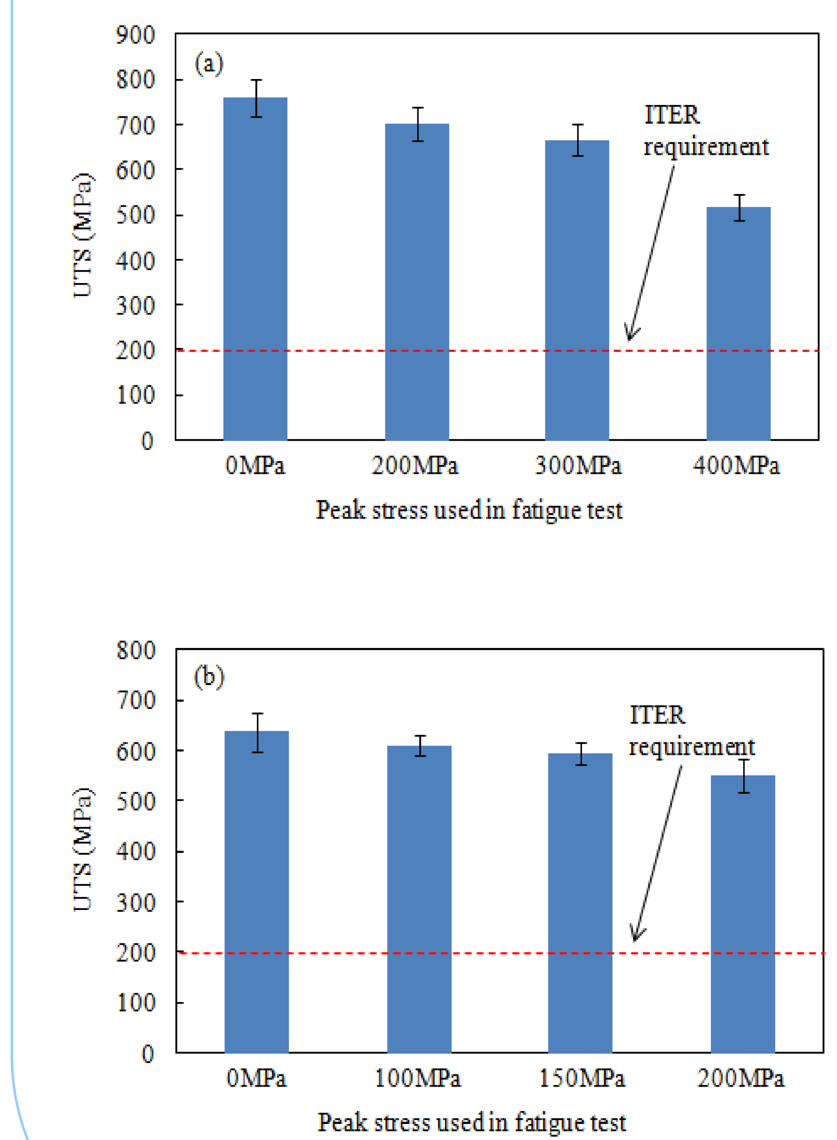


Figure 4. Tensile stress-strain curves of 0° sample (a) and 90° sample (b) after 30,000 cycles



- The stress-strain curve for the composite obtained from the static tensile test is significantly affected by fatigue load. The knee behavior is becoming less obvious as the peak stress used in fatigue tests increases.
- The fatigue load degraded the UTS of the composites and the residual UTS significantly decreases with increasing peak stress used in fatigue tests.
- The residual UTS was more than 200 MPa required by ITER..

Figure 5. The results of UTS for the 0° sample (a) and the 90° sample (b) after fatigue test.

Conclusions

- The ILSS, the static UTS and the residual UTS after 30,000 cycles fatigue test of the composites for both directions satisfied the ITER requirements.
- The mechanical property in 0° direction is better than that in 90° direction.
- The fatigue load degraded the UTS of the composites.

Acknowledgment

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