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Study on the mechanical properties of ice-impregnated HTS coils under confining pressure

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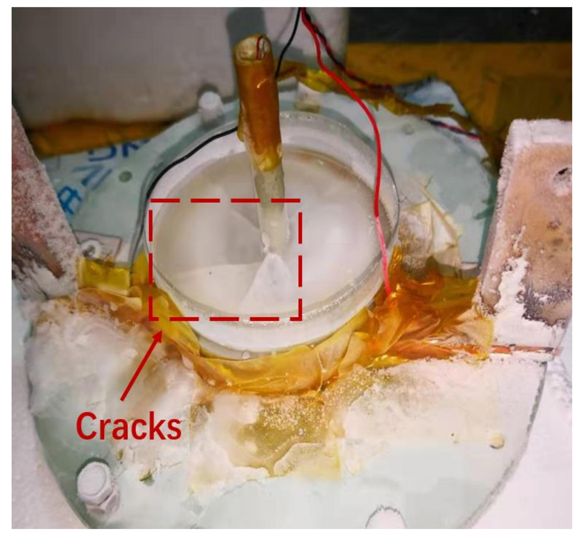
I. Introduction

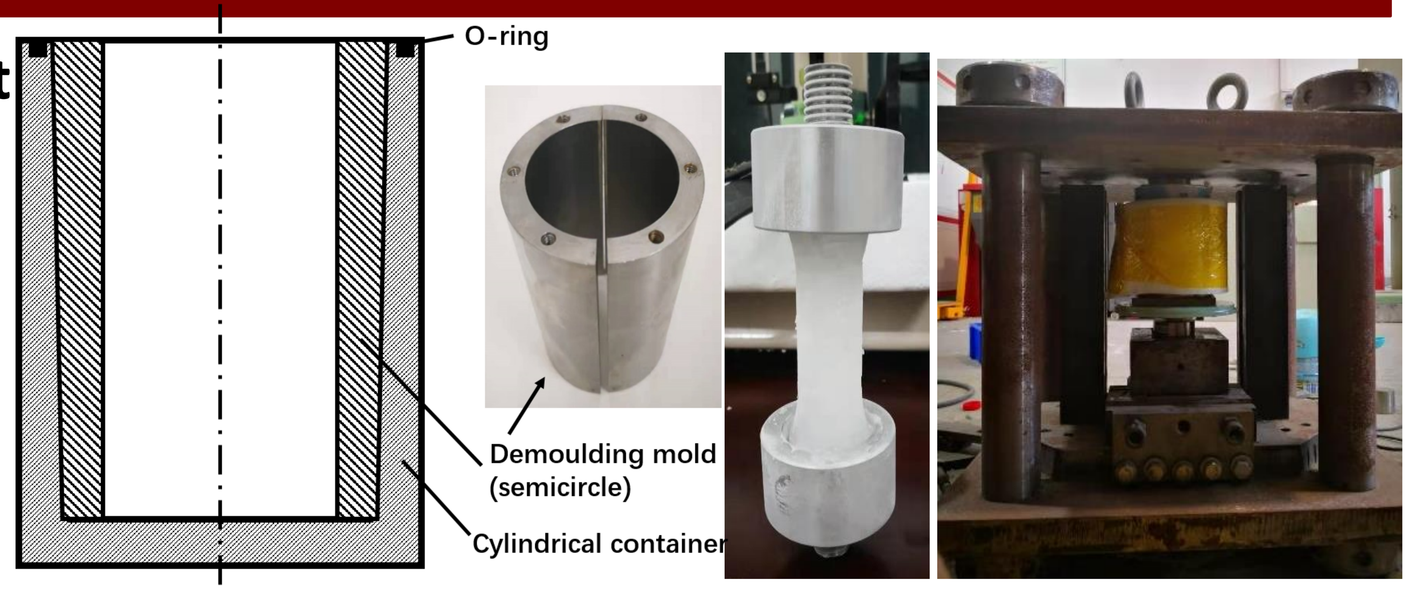
Epoxy resins are commonly used to impregnate the HTS coils for mechanical reinforcement. However, performance degradation of the epoxy impregnated HTS coils is inevitable due to the different thermal expansion coefficients between the epoxy resin and the HTS tape. The ice impregnation technique of pulsed magnets was applied to HTS coils for the first time. But cracks were easily formed in ice during cooling process and the mechanical strength of ice was rarely studied at 77K. To solve this problem, we introduce the technique of ice impregnation under confining pressure. In this paper, uniaxial tension and compression tests of ice were conducted in liquid nitrogen. And critical current of the HTS coil was measured in the closed container. The results showed that ice impregnated HTS coil under confining pressure did not have performance decay and the mechanical strength of them were significantly improved.



II. Experimental setup

2.1 Fabrication of ice for compression and tension test

- A stainless steel container was used to make ice samples under constraints. After the water filled the container, a stainless steel cover was placed on top.
- The entire device was pressed between the upper and lower metal plates by bolts.

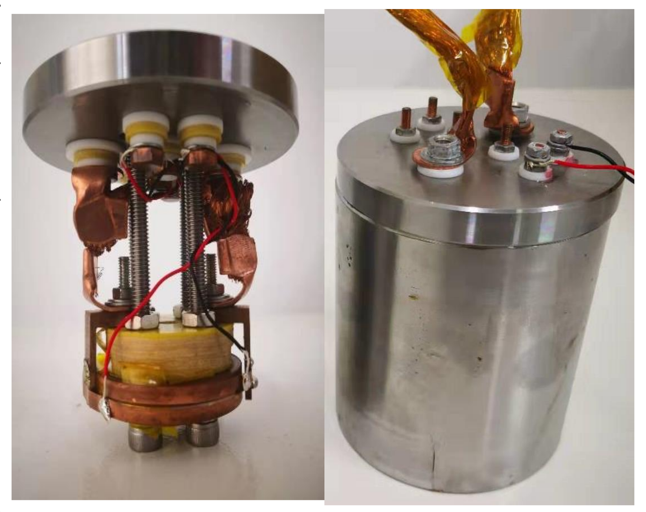


2.2 Fabrication of HTS coils

a) A 2G HTS pancake coil with an inner diameter of 40 mm was fabricated using YBCO tape Superpower SCS-4050.

b) The ice-impregnated coil was a completely enclosed structure. The copper pole was fixed on the cover for connecting the coil to the external power supply. They were designed to be bolt-shaped and could withstand huge internal stress.

Components	Parameters	Specifications
YBCO/Cu tape (Superpower SCS4050)	Conductor width	4.1 mm
	Conductor thickness	90 um
	I_c @ 77 K, self-field	140 A
Pancake coil	Insulation	NI
	Winding structure	Double pancake
	Inner Diameter	40 mm
	Outer Diameter	45.7 mm
	Turns of single pancake	30
	Length	830 cm
	Inductance	209 uH



III. Result and Discussion

3.1 Critical current test

- Figure 3-1 showed representative I-U curve of HTS coil without ice impregnation and HTS ice coil under confining pressure.
- Figure 3-2 showed critical current of HTS coil without ice impregnation and HTS ice coil under confining pressure after several tests.

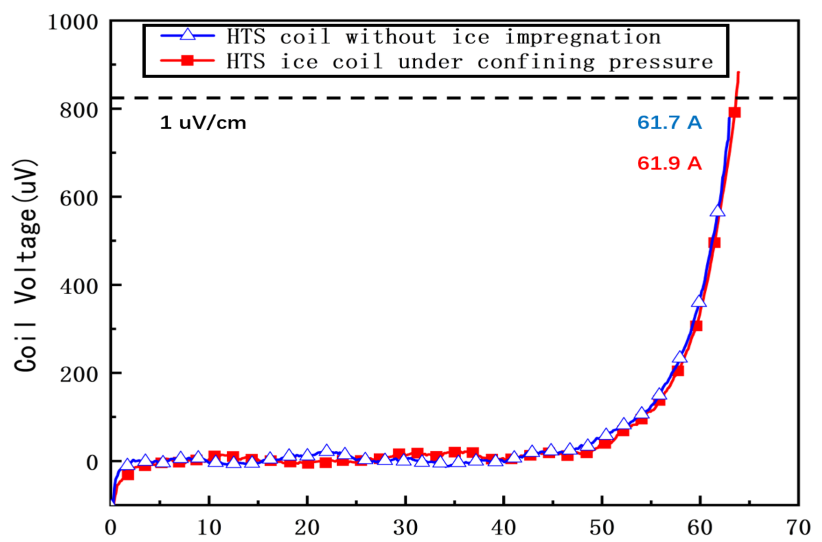


Fig. 3-1

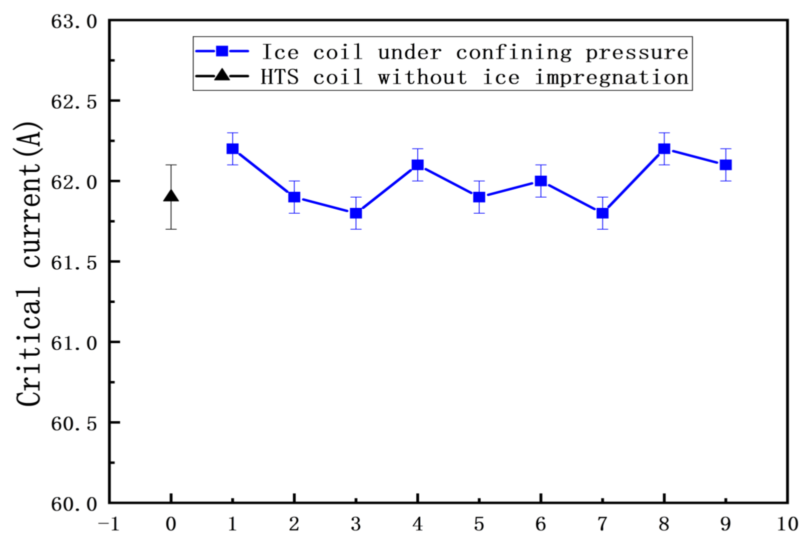


Fig. 3-2

- ✓ **Ice impregnated HTS coil under confining pressure did not have performance decay in critical current.**

3.2 Cracks detection

- An ultrasonic flaw detector (Olympus OMNISX-PA) was used to detect cracks in ice.
- Figure 3-4 (a) showed picture of ice under confining pressure and (b) showed curve of ice without confining pressure.
- ✓ **Cracks in ice samples under confining pressure were fewer than that of ice samples without confining pressure.**


Fig. 3-3

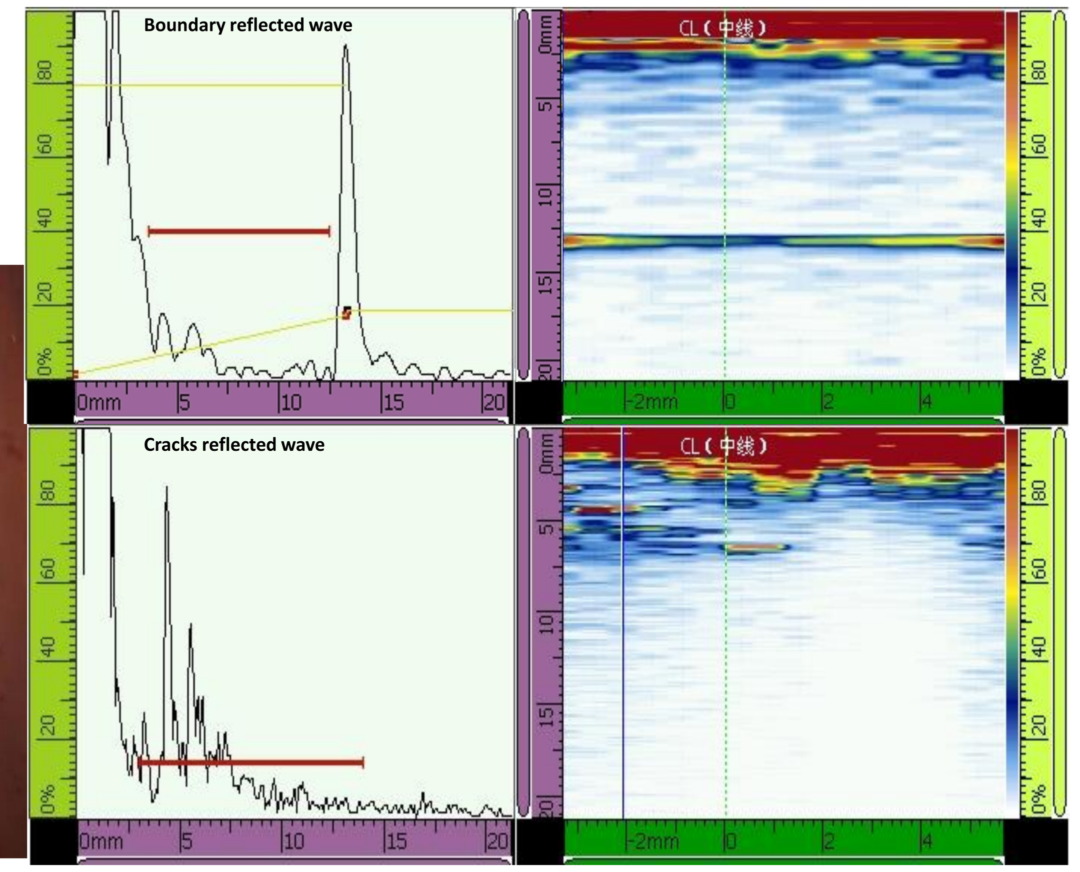
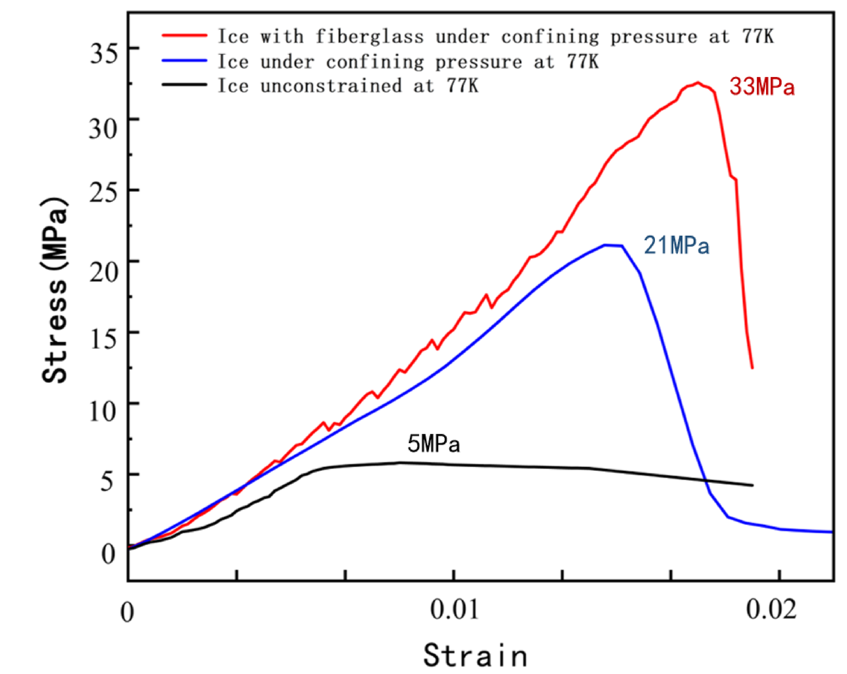


Fig. 3-4

3.3 Uniaxial compression and tension tests

- Figure showed stress-strain curve at 77K for uniaxial compression test: (1)ice with fiberglass under confining pressure (2)ice under confining pressure (3)ice unconstrained
- ✓ **Results showed that ice under confining pressure(21MPa) could significantly improved the compression stress than ice unconstrained (5MPa). 4 times larger.**
- ✓ **Results showed that ice under confining pressure(6MPa) improved the tension stress than ice unconstrained (4MPa). 1.5 times larger.**



IV. Conclusion

- ✓ Ice impregnated HTS coil under confining pressure did not have performance decay in critical current.
- ✓ Cracks in ice samples under confining pressure were fewer than that of ice samples without confining pressure.
- ✓ Results showed that ice under confining pressure(21MPa) could significantly improved the compression stress than ice unconstrained (5MPa). 4 times larger.
- ✓ Results showed that ice under confining pressure(6MPa) improved the tension stress than ice unconstrained (4MPa). 1.5 times larger.
- ✓ Mechanical strength of ice under confining pressure were significantly improved.

References

1. Guangda Wang, et al. "A new method to avoid critical current degradation of YBCO coils by ice impregnation", Supercond. Sci. Technol. 32 (2019) 105011 (7pp)
2. E. Schulso, "THE FRACTURE OF ICE Ih," Journal de Physique Colloques, 48 (C1), 1987, pp.C1-207-C1-220.