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Resistances between soldered YBCO tapes consisting of the stacked cable

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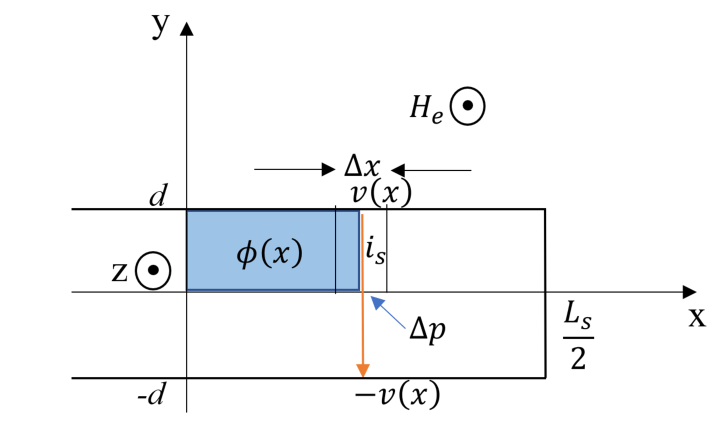
Abstract

In order to clarify the electromagnetic properties of a conductor made of laminated YBCO tapes, we report the results of investigating the effect of solder connections on the resistance between the tapes. YBCO laminated conductors are being researched and developed as candidates for large 100 kA class conductors for nuclear fusion. In order to quantitatively understand the electromagnetic properties of such conductors, such as the rolling current and coupling loss characteristics, it is important to accurately evaluate the inter-tape contact resistance. In this study, the inter-tape coupling loss of a conductor consisting of 50 stacked wires was measured in liquid nitrogen. Two types of measurement samples were used, one with soldered inter-tape connections and the other without. For the solder-connected samples, solder-plated copper laminated wires were laminated, and the entire sample was fixed with copper tape and then impregnated with solder. For the unsoldered samples, the copper laminated wires were laminated in air and fixed with polyimide tape. The sample was about 100 mm long without twisting, and the measurement was conducted under the condition that the coupling current flowed over the entire length of the sample. The inter-tape resistance is estimated from the comparison between the measured and theoretical analysis of the coupling loss, and the effect of the solder connection is discussed.

coupling time constant



$$v = d\dot{B}x$$

$$i = gv$$

$$y_0 = 2gv^2$$

$$= 2gd^2\dot{B}^2x^2$$

$$W_c = 2\int_0^{\frac{L_c}{2}} 2gd^2\dot{B}^2x^2\,dx$$

$$= A^*\tau\mu_0\dot{H}_e^2$$

$$A^*\tau = \frac{W_c}{\mu_0\dot{H}_e^2}$$

W_c	Coupling loss[J/m³]
H_e	magnetic field [T]
A^*	Factor by cross-sectional shape
τ	coupling time constant [s]
μ_0	Permeability in vacuum
g	inter tape conductance

Measurement sample

Fig1. Soldered model conductor

Fig2. Not Soldered model conductor

Wire type：YBCO		
	soldered	Not soldered
Sample width [mm]	6	6.25
Sample thickness [mm]	7	5.65
Sample length [mm]	96	100
Number of wires [wires]	50	50
Ic of wire [A]	200	250
Refrigerant	Liquid nitrogen	

Measurement method

<Pick-up coil method>

The pick-up coil surrounds the whole sample. The roles of the cancel-coil are the following two: The one is canceling the inductive component of the voltage of the pick-up coil, and the other is the detection of the external magnetic field.

☐The magnetic field dependences
The amplitude of the magnetic field was up to 797mT.

☐The frequency dependencies were measured.
The frequency was up to 360 Hz.

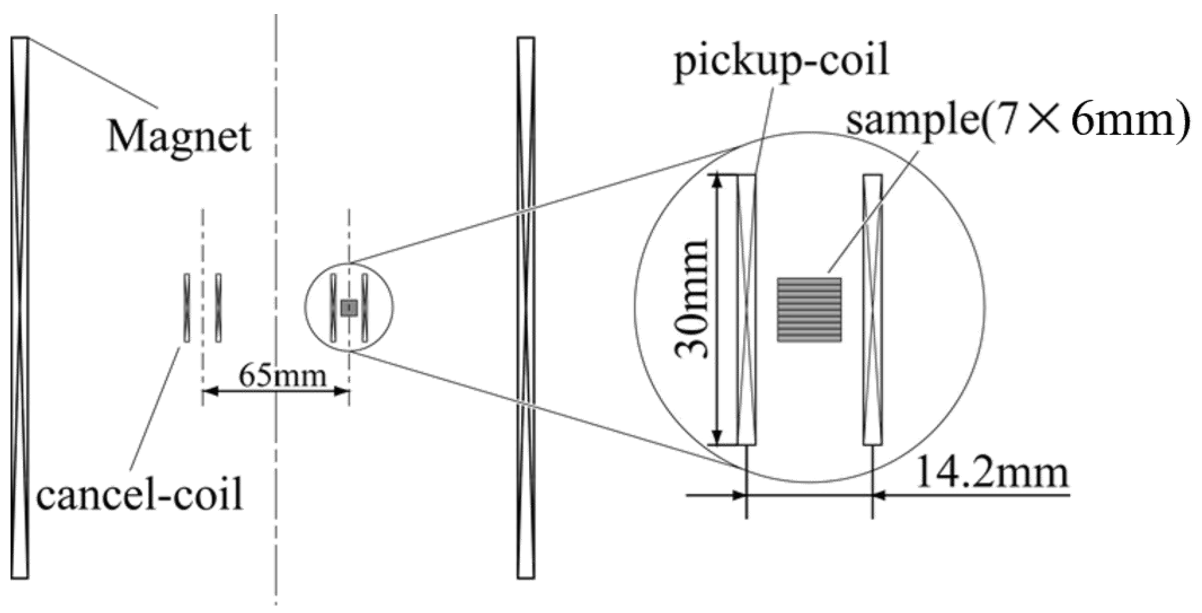


Fig. 2 Pick-up coil arrangements for measuring ac losses in the short sample of the model conductor composed of the stacked 50 YBCO tapes.

Experimental Result

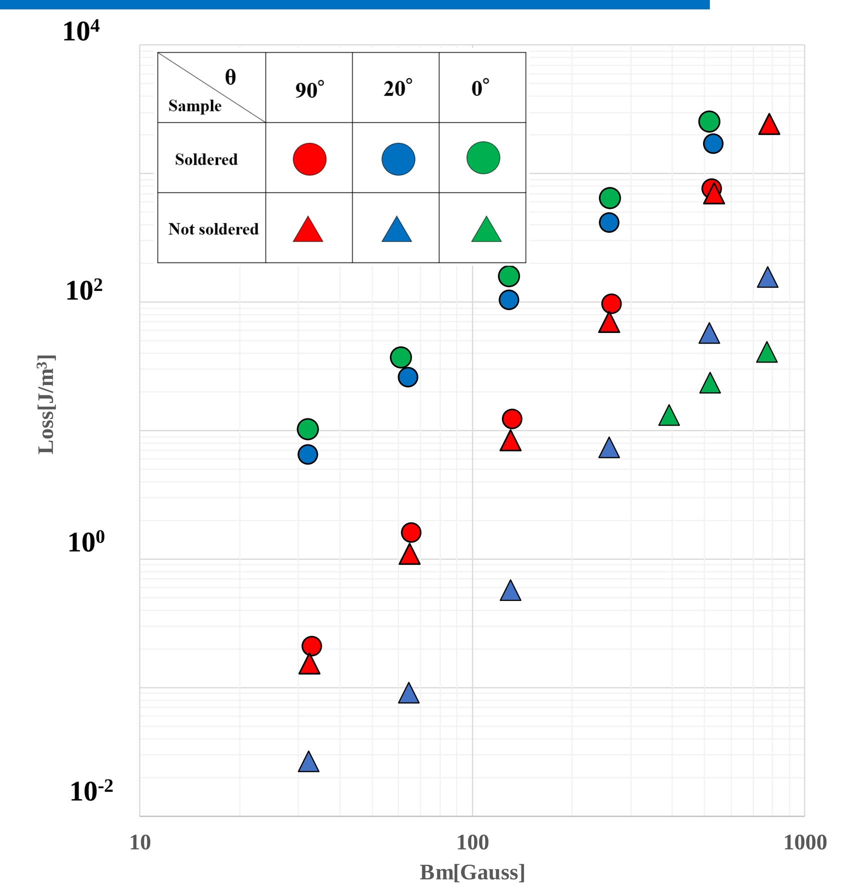


Fig. 3 Measured ac loss properties. The angles are formed by the applied magnetic field and the flat face of the tape. is between magnetic fields and the tape face.

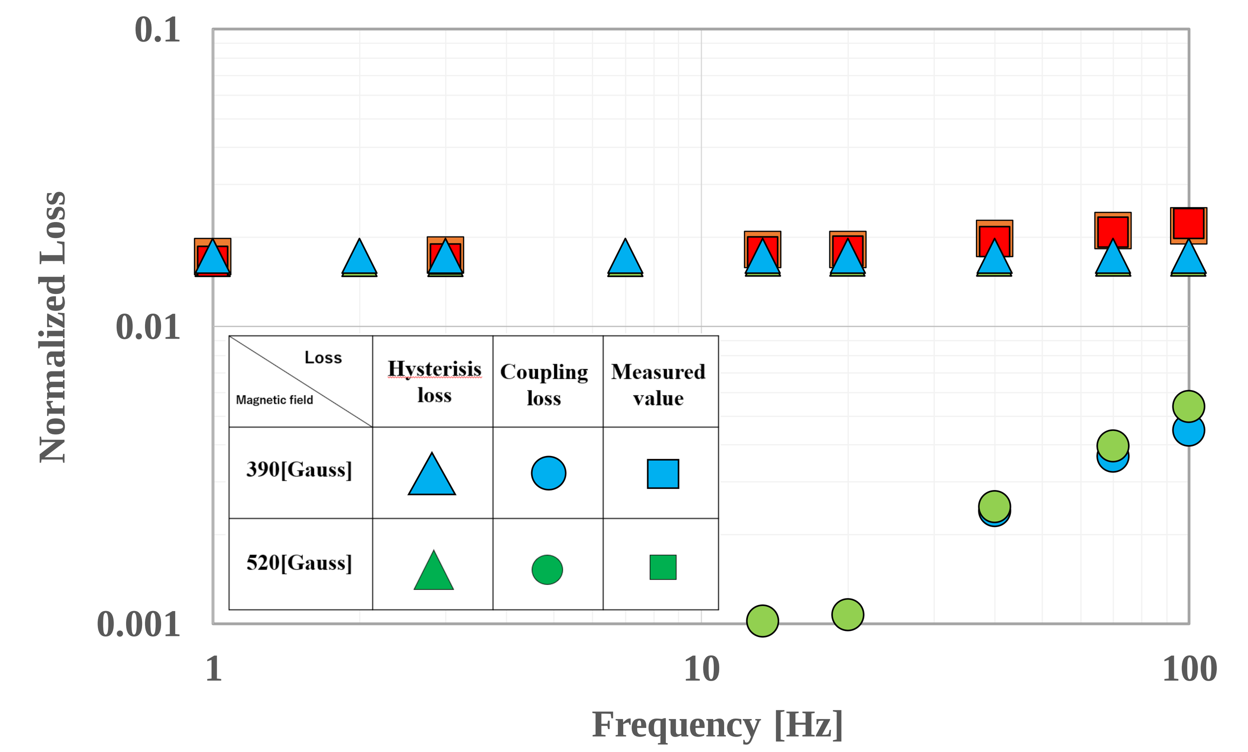


Fig.4 Frequency dependences of AC losses in no soldered sample when magnetic fields applied to the parallel to the tape face. Hysteresis losses without frequency dependencies were observed. This cause is that tapes were tilted and curved (see Fig. 2). The measured losses separate into hysteresis losses and coupling losses. Triangle and circle plots represent hysteresis and coupling losses, respectively.

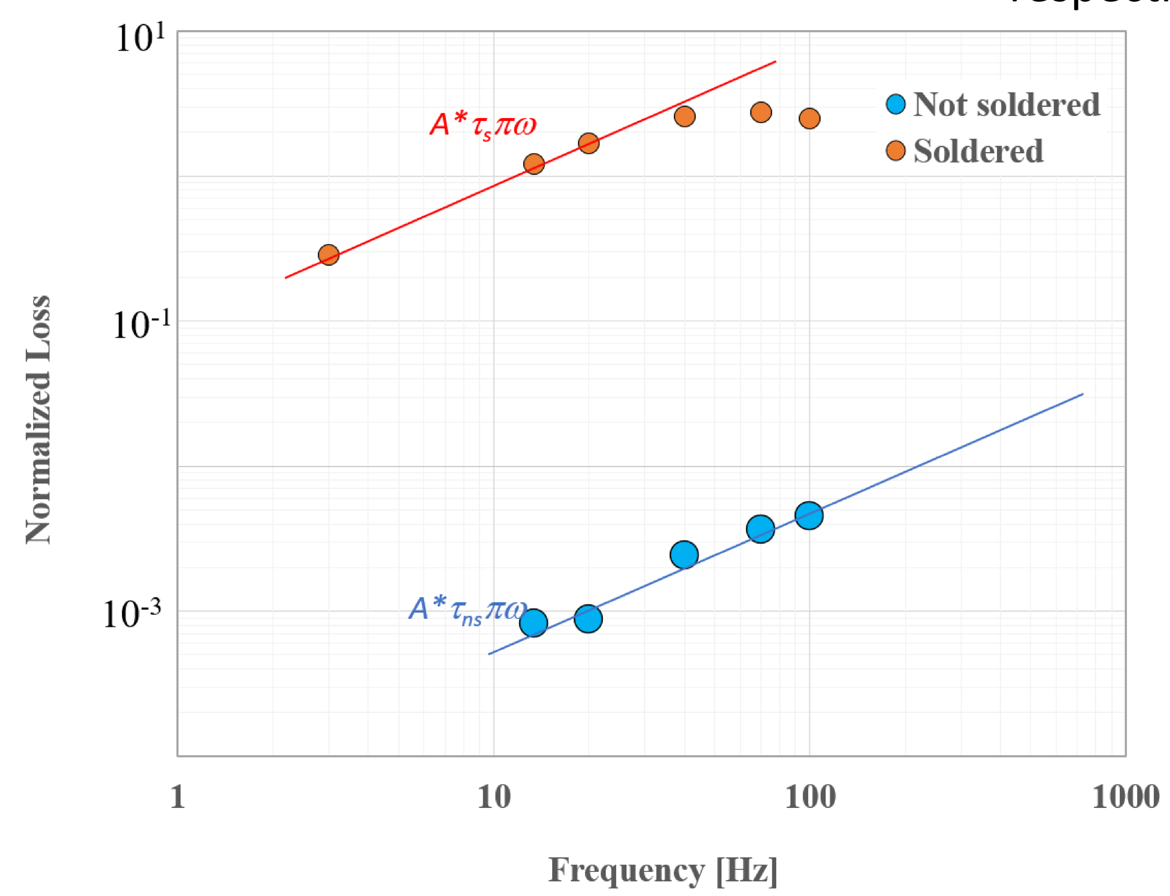


Fig. 5 Frequency dependencies of the coupling losses. Red and blue plots represent the coupling losses in the soldered and not soldered

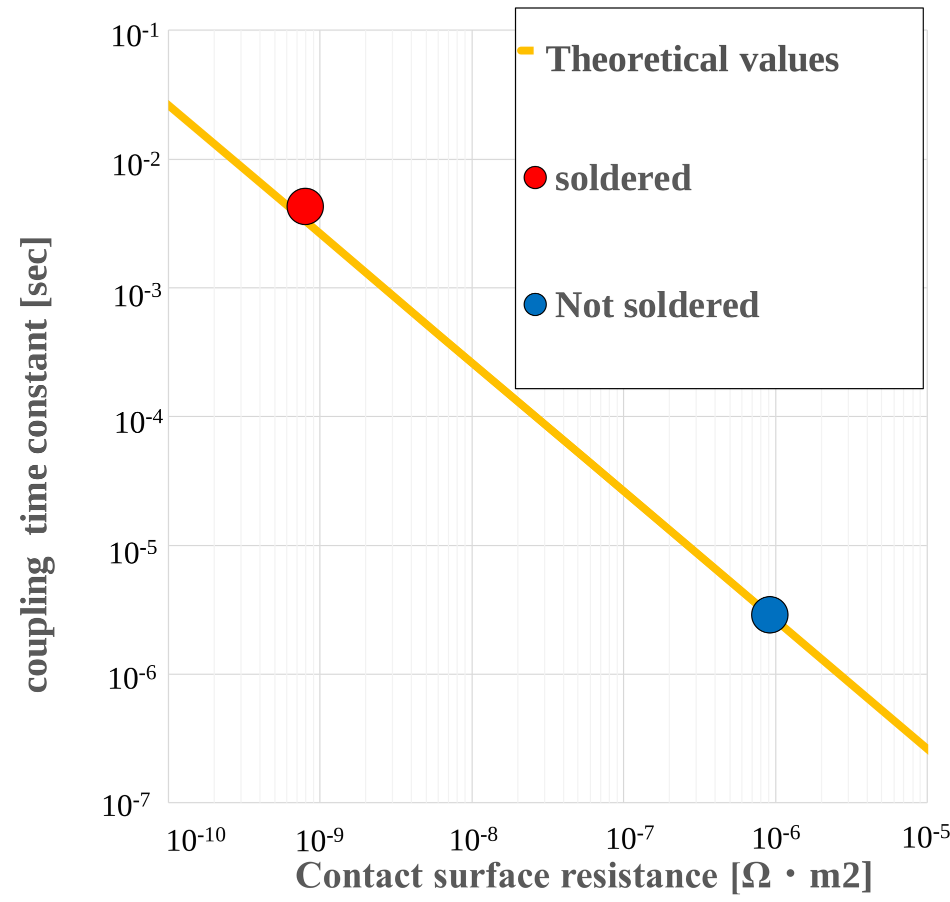


Fig.6 Coupling loss time-constants vs inter-tape resistances

Inter-tape resistances were estimated 8 x 10^{-10} Ωm² and 9 x 10^{-7} Ωm² for the soldered and the no soldered samples, respectively. In the soldered sample, inter-tape resistances decrease to 3 orders smaller than that of the no soldered samples.

Conclusion

Ac losses in the stacked YBCO tapes conductors with and without soldered were measured, and evaluated inter-tape resistances from coupling loss properties.

- The inter-tape resistances of the soldered and no soldered samples were evaluated 8 x 10^{-10} Wm² and 9 x 10^{-7} Wm², respectively.
- The inter-tape resistances were reduced by about three orders of magnitude with the solder connection.