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Comparison and analysis of inductance according to toroidal winding type of superconducting element combined the DC circuit breaker

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Abstract

- DC Interruption technology is essentially required as DC system and microgrid have increased.
- Until now, many hybrid Interruption technologies have been proposed in which a semiconductor element or a superconducting element is combined with a mechanical DC circuit breaker.
- In this paper, we experimented using a DC circuit breaker that combines superconducting elements.
- Resistive superconducting elements are simple structures. And it exhibits different characteristics depending on its shape, material, and length.
- The purpose of this study is to maximize the efficiency of the superconducting element by changing the winding shape, material, and length.

Experiments

1) Design of cores

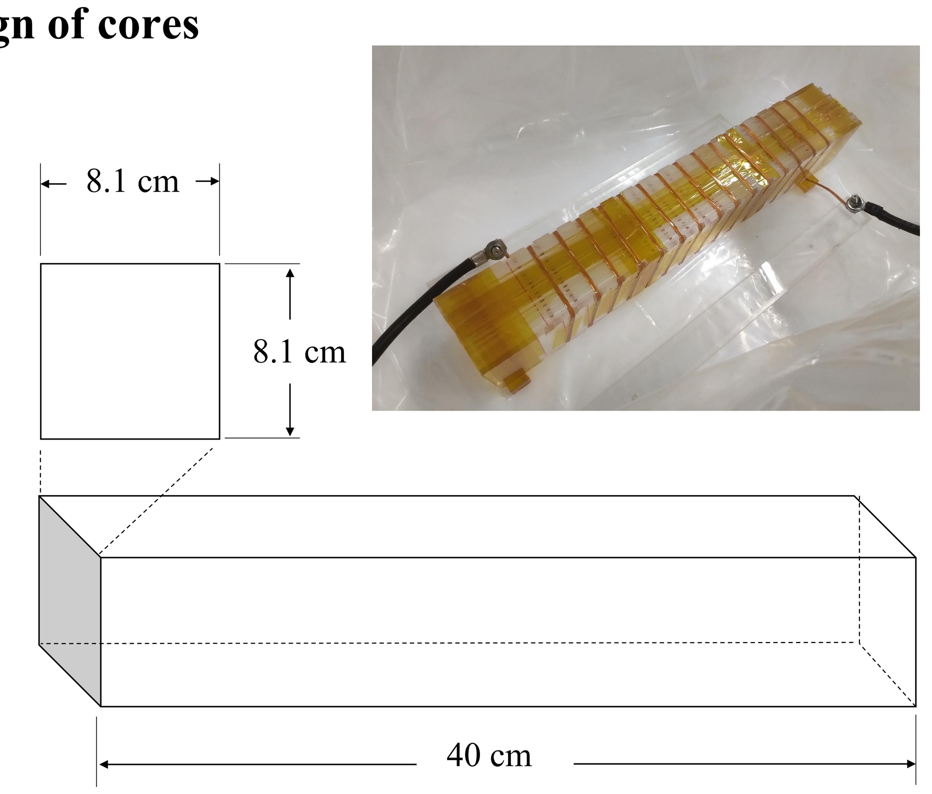

Fig. 1. Solenoid core

$$L = \frac{N^2 \mu A}{l}$$

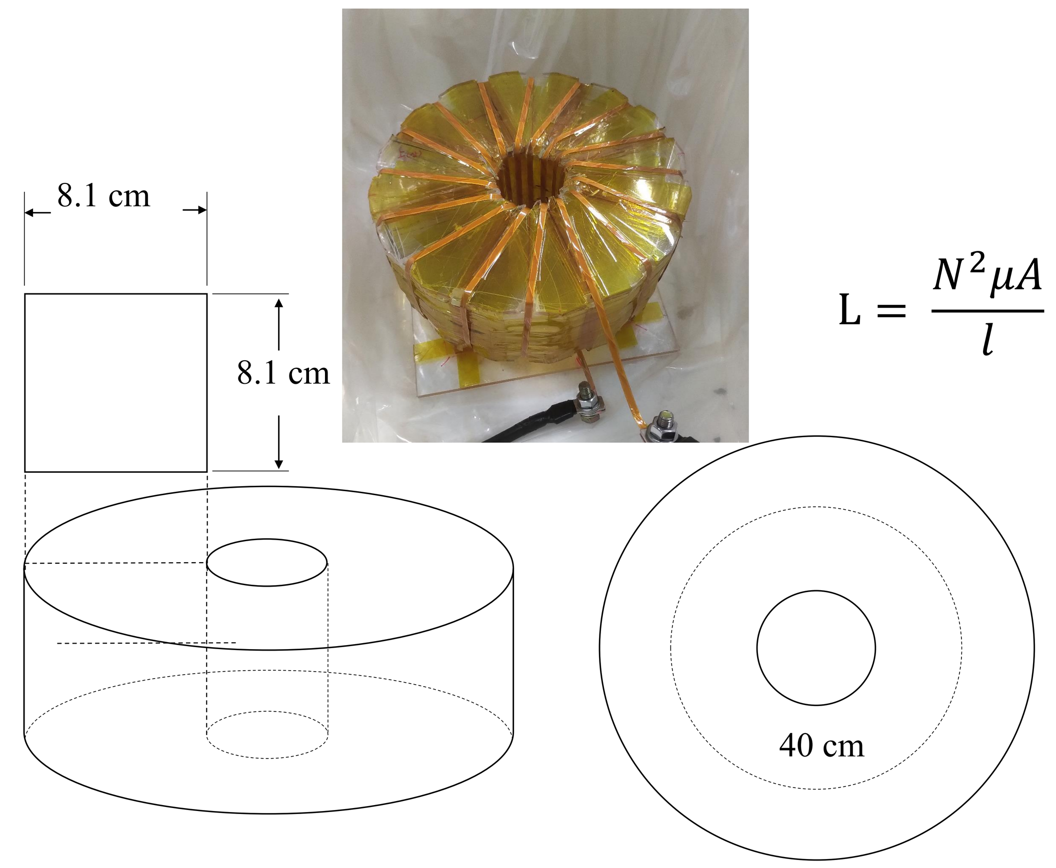

Fig. 2. Toroidal core

Table 1. Superconducting element parameters

SuNAM GdBCO 2G HTS Wire	
Stabilizer	Cu
Length	$5\ [m]$
Thick	$0.14\ [mm]$
Wide	$4.1\ [mm]$
Critical current	$200\ [A]$

Table 2. Core parameters

	Solenoid	Toroidal
Magnetic permeability (μ)	1.25×10^{-6} ($Plastics$)	1.25×10^{-6} ($Plastics$)
Area of coil (A)	$65.61\ cm^2$	$65.61\ [cm^2]$
Number of turns (N)	15.5	15.5
Average length of coil (l)	$40\ cm$	$40\ [cm]$
Volume of core	$2624.4\ cm^3$	$2624.318\ [cm^3]$

2) Resonant DC circuit breaker

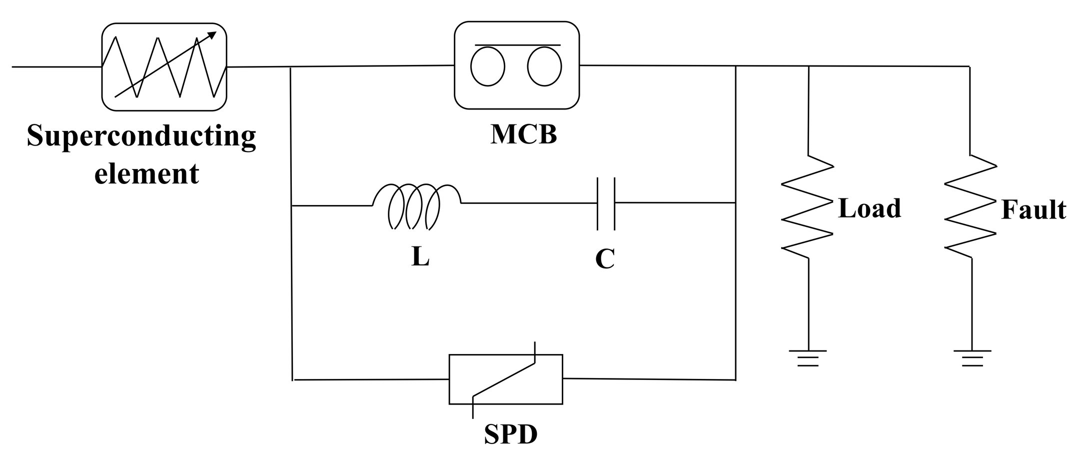

Fig. 3. Experimental circuit

Table 3. Experimental parameters

DC Voltage	$500\ [V]$
Steady state current	$47\ [A]$
Fault state current	$506\ [A]$
L	$55\ [\mu H]$
C	$205\ [\mu F]$

3) Results

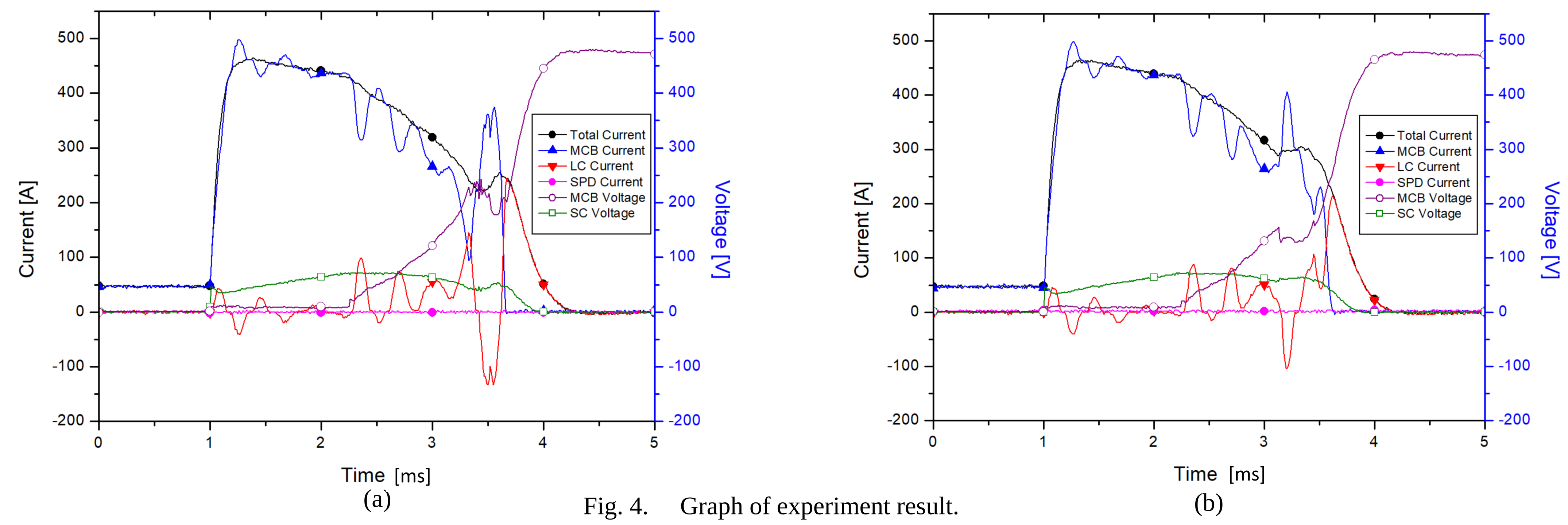

Fig. 4. Graph of experiment result. (a) solenoid, (b) toroidal

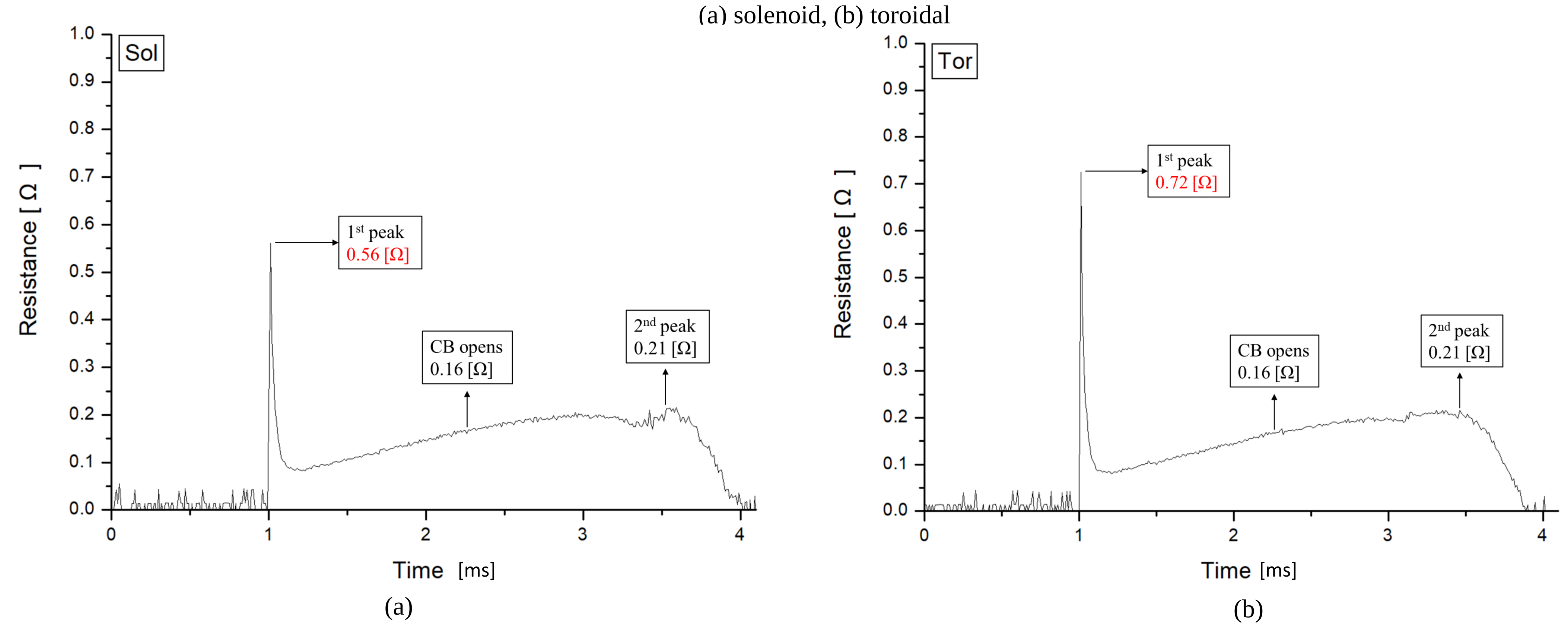

Fig. 5. Resistance graph of superconducting element. (a) solenoid, (b) toroidal

Table 3. Results of the experiment

		Solenoid	Toroidal
Average current (steady state)		47 [A]	47 [A]
Initial fault current		463 [A] (1.3 [ms])	463 [A] (1.3 [ms])
Superconducting element resistor	1st peak	0.56 [Ω] (1.01 [ms])	0.72 [Ω] (1.01 [ms])
	When the DC breaker opens	0.16 [Ω] (2.24 [ms])	0.16 [Ω] (2.24 [ms])
	2nd peak	0.21 [Ω] (3.59 [ms])	0.21 [Ω] (3.46 [ms])
Interrupting time		3.28 [ms]	3.2 [ms]

Conclusion

- We compared the resistance of the solenoid type and toroidal type core by an experiment.
- As a result, the toroidal type superconducting element generated more impedance than the solenoid type at the first peak point.
- The toroidal type has no leakage flux, so it can generate more inductance than the solenoid type.
- In the future, we plan to analyze using superconducting wires of more lengths.

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