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Magnetization Loss estimation of HTS Solenoid Coils wound with CORC®

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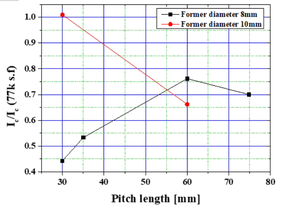
1. Introduction

- ✓ The HTS power devices should have low AC losses. For applying HTS to power device, HTS cable should be stacked with multiple tapes with narrow strands or striated ones. If the ends of each strand are connected, AC losses don't decrease in straight tapes. But in the case of CORC® even if both ends of the strands are connected, AC losses decrease.
- ✓ The decrease of AC losses is not only proportional to the number of striation but also to the applied fields. We compared the losses of CORC® samples of various widths with the ones of the straight samples.
- ✓ We calculated the magnetization losses of the CORC® coil. We also compared the losses of coils with different tape widths.

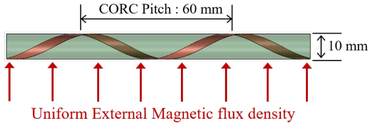
2. Specifications of Samples

[TABLE 1. Specifications of samples]

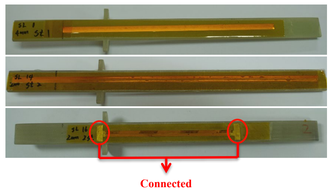
	Parameters	Values
HTS tape	Width	2 mm, 4 mm, 6 mm
	Thickness	0.15 mm
	Critical current	83 [A], 180 [A], 313 [A]
	Manufacture	SuNam
CORC®	Diameter	10 mm
	Pitch of CORC®	60 mm
	Former material	FRP



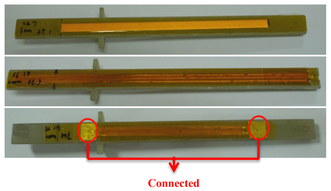
[Fig. 1. Critical currents of CORC® samples by pitch lengths and former diameters]



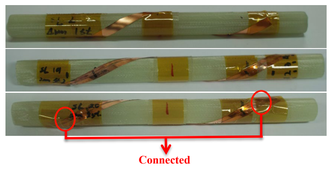
[Fig. 2. CORC® shape]



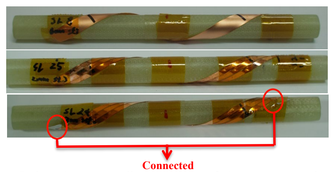
[Fig. 3. Straight samples of 4mm x 1 and 2mm x 2 (open and connected ends)]



[Fig. 4. Straight samples of 6mm x 1 and 2mm x 3 (open and connected ends)]

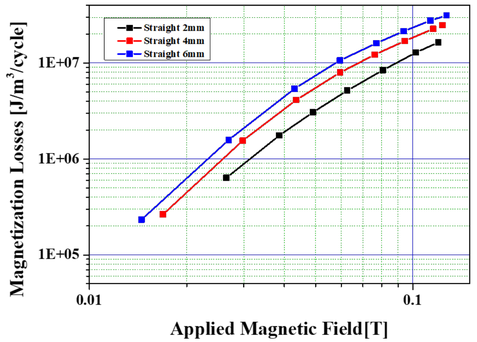


[Fig. 5. CORC® samples of 4mm x 1 and 2mm x 2 (open and connected ends)]

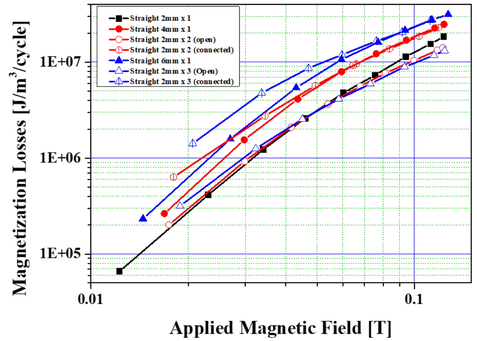


[Fig. 6. CORC® samples of 6mm x 1 and 2mm x 3 (open and connected ends)]

3. Magnetization losses of straight and CORC® samples

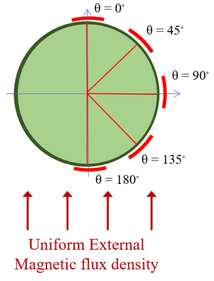


[Fig. 7. Magnetization losses of Straight 2mm, 4mm, 6mm]

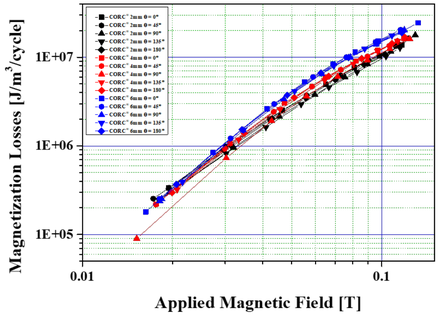


[Fig. 8. Magnetization losses of straight all of samples]

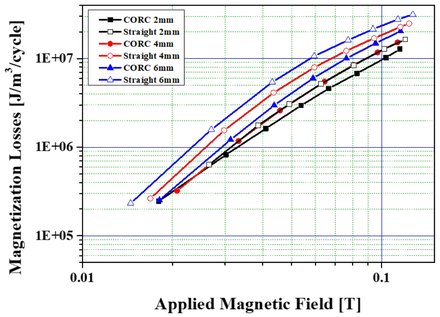
- ✓ Losses of straight samples of 2mm x 2 (open) showed a similar pattern to the one of straight 4mm x 1 sample. But straight samples of 2mm x 2 (connected) had 58.9 % of the losses of straight samples of 4mm x 1 in 0.1 T.
- ✓ Straight samples of 2mm x 3 (connected) had higher losses than the ones of straight 6mm x 1 in low field, but as the field increased, the losses became to coincide with each other. In straight samples of 2mm x 3 (open), the losses were lower than the ones of straight 6mm x 1 in all region and the magnitude was 58.9 % of the loss of the 6mm x 1 in 0.1 T.
- ✓ Because the screening current can flow through connected ends, the losses of the samples with connected ends may be higher than the ones of unconnected samples.
- ✓ Losses of the 2mm x 2 (open) and had similar values with the ones of 2mm x 3 (open) over 0.04 T.



[Fig. 9. Figure of CORC® by angle]

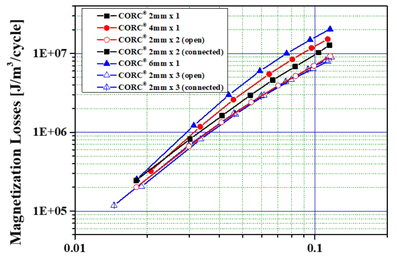


[Fig. 10. Magnetization losses of CORC® 2mm, 4mm, 6mm by angle]



[Fig. 11. Magnetization losses of 2mm, 4mm, 6mm straight and CORC®]

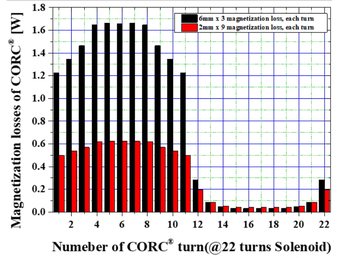
- ✓ We measured the losses of CORC® samples at various winding start angles in LPC(linked pick-up coils) region. Fig. 10 shows that losses of CORC® are almost same in which samples as the angle changes.
- ✓ Comparing the straight and CORC® samples, the losses of CORC® 2mm, 4mm, 6mm samples were 78.1 %, 65.4 %, 67.8 % of the straight 2mm, 4mm, 6mm samples.



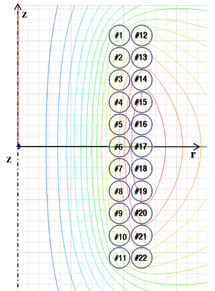
[Fig. 12. Magnetization losses of CORC® all of samples]

- ✓ In the case of CORC®, even if the ends of multi tapes were connected, losses didn't increase unlike straight samples.
- ✓ Also the losses of all 2mm multi tapes samples were similar.

4. Loss calculation of solenoid coils wound with different CORC®



[Fig. 13. Magnetization losses of CORC® coil with 6mm, 2mm]



[Fig. 14. Flux liens of CORC® coil]

[TABLE 2. Specifications of CORC® coils]

		HTS tape width	Num. of tapes	Critical current (@77 K, Self-field)	Inner radius	Num. of turns	Operating current	Operating temperature	Coil layers	Total loss
Multi-tapes HTS Conductor	CASE. 1	6 mm	3	313 A	43 mm	22	360 A	77 K	2	17.3 W
	CASE. 2	2 mm	9	83 A	43 mm	22	360 A	77 K	2	7.18 W

- ✓ We calculated the losses of coils made with CORC® 2mm x 9 and CORC® 6mm x 3.
- ✓ The loss of the coil with CORC® 2mm x 9 was 7.18 W and the other was 17.3 W.

5. Conclusion

- ✓ To apply HTS cables to power devices, they should have low AC losses.
- ✓ We compared the losses of straight samples with the ones of CORC® samples. In the case of straight samples, there was no loss reduction effect if the multi tapes of narrow width were connected at the ends. But even if each tape was connected or disconnected, CORC® samples showed the loss reduction effect.
- ✓ To estimate the magnetization losses of CORC® coils with 2mm x 9, we first calculated the losses of the CORC® coil with 6mm x 3. And then we applied the loss ratios from the results of CORC® 2mm x 3 and CORC® 6mm x 1 according to the magnetic field.