Study of REBCO Trapezoidal Armature Windings for Superconducting Induction Motor

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Introduction

REBCO-tapes are difficult to manufacture complex armature windings having the same forms used copper wires because of mechanical characteristics. In preceding studies, racetrack coils were used for armature windings. In this case, the bend radius and the distance of adjacent coils restrict the winding number, the coil pitch, and the distance between the rotor and the coil. In this study, considering characteristics of REBCO tapes, we proposed trapezoidal coils for armature windings. Trapezoidal coils with wider pitches than racetrack coils under the exact condition of distance between the rotor and coils. We executed electromagnetic simulations about 2 kW-class motors having two kinds of armatures using the infinite element method to investigate the differences of two motors' characteristics.

Designs of induction motors

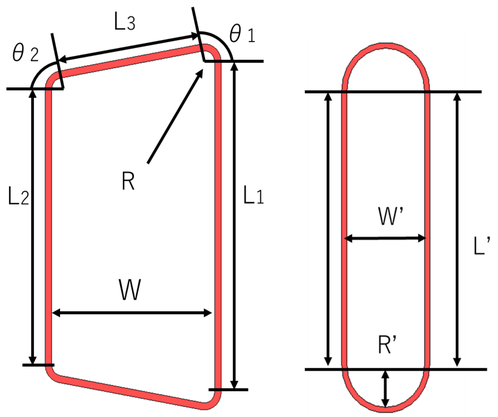

Fig.1 Trapezoidal coil and Racetrack coil

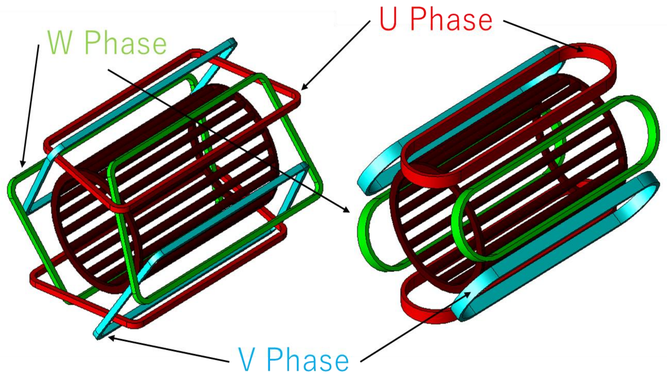

Fig. 2 Two types of induction motors

TABLE I
MAIN SPECIFICATIONS OF TWO COILS

L1: Lower base [mm]	300
L2: Upper base [mm]	250
L3: Leg [mm]	142
W: Coil pitch [mm]	10
R: Bend radius	10
θ1: Large bend angle	1000
θ2: Small bend angle	80
L': Straight section	250
W': Coil pitch	69.6
R': Bend radius	37.6

TABLE II
MAINLY SPECIFICATIONS OF INDUCTION MOTORS

	Trapezoidal coils	Racetrack coils
Motor diameter [mm]	254	219
Rotor diameter [mm]	160	
Rotor's effective length [mm]	250	
Number of rotor bars	24	
Number of poles	2	
Rotor weight [kg]	4.48	
Number of turns per phase	100	160
Coils weight [kg]	1.43	1.88
Tape length of coils [m]	551	724

constraint condition
- Motors' output is about 2 kW at 64 K
- Armature voltage and current amplitude are 120 V and 150 A by equipment's load limitation
- Armature coils are about 10 mm from next to coils

Analysis results and considerations

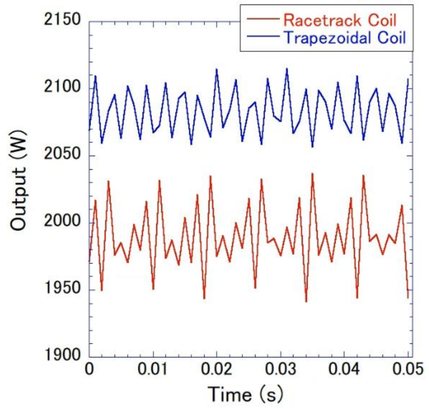

Fig.3 Comparison of output about two motors with different coils

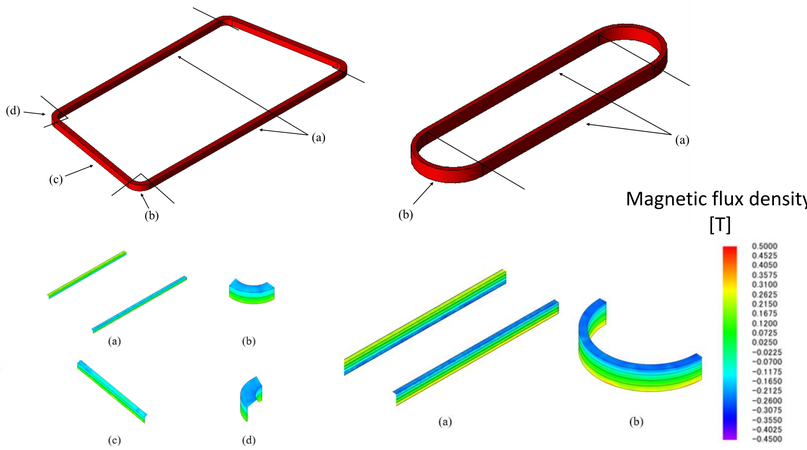

Fig.4 Vertical component of magnetic flux density penetrating REBCO tapes of two types coils

The motor with trapezoidal coils show smaller torque ripple than racetrack coils .

Vertical component of magnetic flux density at trapezoidal coil are smaller in all parts than racetrack coil. .

TABLE III
COMPARISON OF RESULTS OF SIMULATIONS

	Trapezoidal coils	Racetrack coils
Maximal vertical component of magnetic flux density [T]	0.344	0.493
voltage amplitude [V]	93.4	110
Load factor of coils [%]	39.6	49.9
AC loss of coils [W]	99.4	242
Output per meter of REBCO tapes [W/m]	3.79	2.77

Because of small vertical component of magnetic flux density and number of trapezoidal coils, AC loss of trapezoidal coils are smaller than racetrack coils.

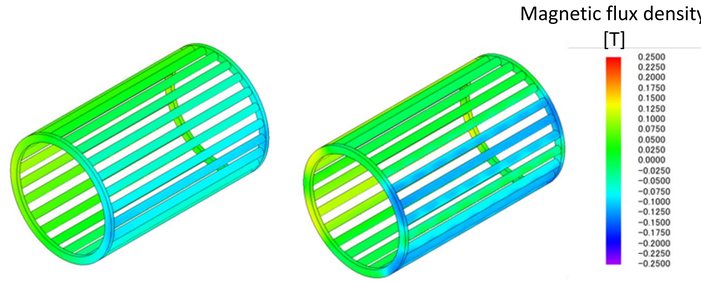

Fig.5 Vertical component of flux density of rotor at first step of simulations
(a): trapezoidal coils (b): racetrack coils

Because of the difference of rotating magnetic field, the vector of current density of rotor made by racetrack coils are influenced. Then, the motor with trapezoidal coils shows smaller winding number of coils and larger output than racetrack coils.

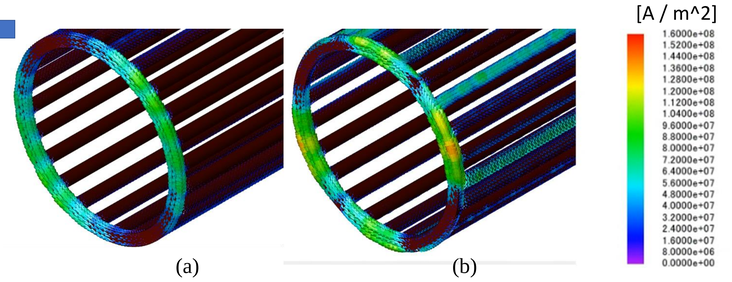

Fig.6 Vector of current density of the rotor (a): trapezoidal coils (b): racetrack coils

Conclusion

In this study, we proposed trapezoidal coils as armature windings of superconducting induction motors. Trapezoidal coils shows more superiority about rotating magnetic field, torque ripple and AC loss by simulations results than racetrack coils. In the future, we will manufacture an experimental superconducting induction motor and investigate the motor's characteristics.