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Comparison of Different Stator Winding Configurations of Fully High-Temperature Superconducting Induction/Synchronous Motor

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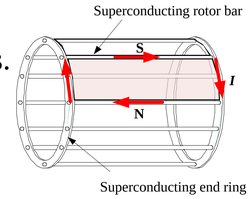
INTRODUCTION

Our group has developed a fully high-temperature superconducting induction/synchronous motor (HTS-ISM) for ship propulsion, bus, and electric vehicles. The stator winding and squirrel-cage rotor winding are fabricated by HTS conductors.

Advantages:

- Coexistence of slip and synchronous modes.
- High efficiency for variable speed control.
- High torque density.
- Robustness against overload.



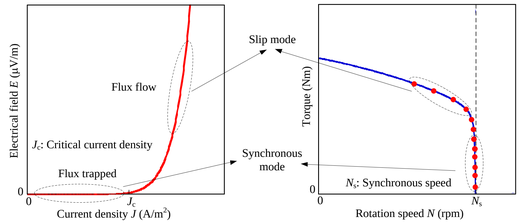
HTS squirrel-cage rotor

Objectives:

- Performance comparison of fully HTS-ISM with different HTS stator winding configurations, such as concentrated winding, distributed winding, and toroidal winding, are lack of attention.
- The current transport property of HTS coils in different stator winding configurations are lack of consideration.

FUNDAMENTAL ROTATION PRINCIPLE

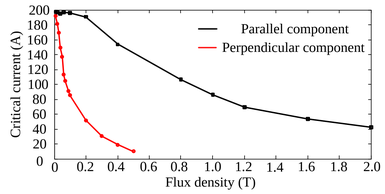
The fully HTS-ISM possesses both of the synchronous mode and the slip mode.



Electrical field (E) vs current density (J) and torque characteristics curve of HTS-ISM

Influence on the current transport property of an HTS tape

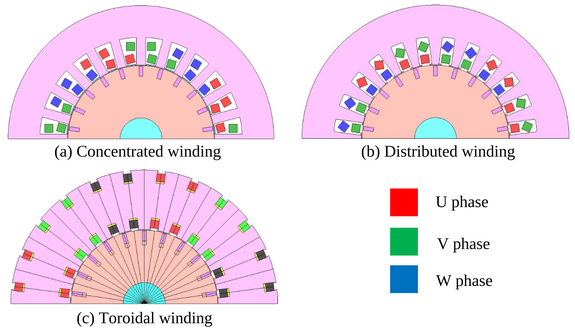
To improve the current transport property of HTS coils, it is necessary to reduce the perpendicular component of magnetic flux density.



Measurement results of a Bi-2223 tape.

DESIGN OF FULLY HTS-ISM

We established three kinds of fully HTS-ISM Finite Element Analysis (FEA) models with different stator winding configurations: concentrated winding, distributed winding and toroidal winding. Due to the limitation of bending diameter and mechanical strength of HTS tapes, the coil pitch of the distributed winding is 2. The HTS stator coils are considered as double-pancake structure.

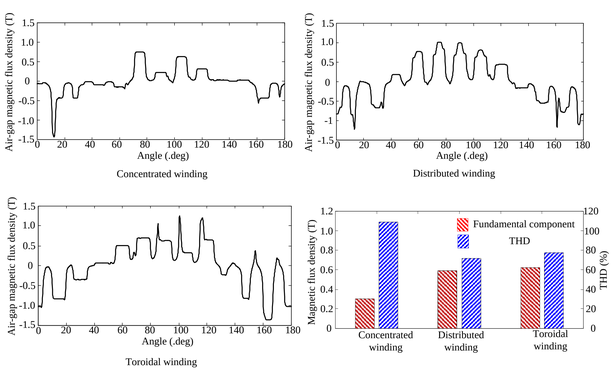


FEA models of fully HTS-ISM with different stator winding configurations

SIMULATION AND COMPARISON

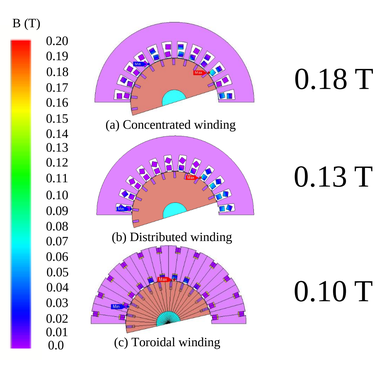
Performance of fully HTS-ISM with three kinds of stator winding configurations are compared based on 2-D FEA simulations. The material of stator as well as rotor winding is Bi-2223 tape. The input current is 50A, the frequency is 50 Hz, and the slip is 0.002.

Air-gap magnetic flux density distribution



Comparison results of air-gap magnetic flux density

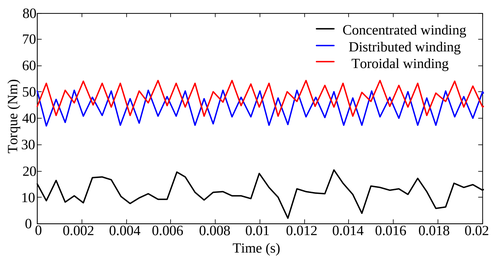
Influence of current transport property of HTS stator coils



Perpendicular component of magnetic flux density distribution of stator winding

Output torque and torque ripple

- **Average torque:**
  Toroidal > Distributed > Concentrated
- **Torque ripple:**
  Toroidal ≈ Distributed < Concentrated



Output torque

CONCLUSION

Item	Concentrated	Distributed	Toroidal
Air-gap flux density (Fundamental)	Small	Middle	Large
THD of air-gap flux density	Large	Small	Middle
Torque	Small	Middle	Large
Torque ripple	High	Low	Low
Current transport property	Worst	Middle	Best

- The rotating performance and current transport property of HTS coils of fully HTS-ISM with different stator winding configurations are compared.
- The fully HTS-ISM with toroidal winding has larger torque density, low torque ripple. Moreover, the toroidal winding can have the smallest perpendicular component of magnetic flux density, so as to have the largest current transport capacity of HTS coils.