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Loss Analysis of a 3 MW HTS Ship Propulsion Motor

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Outline

- Introduction
- **Overview of 3 MW HTS motor**
- **Design for high efficiency**
- **How to analyze loss**
- **Details of loss**
- Conclusion

Introduction

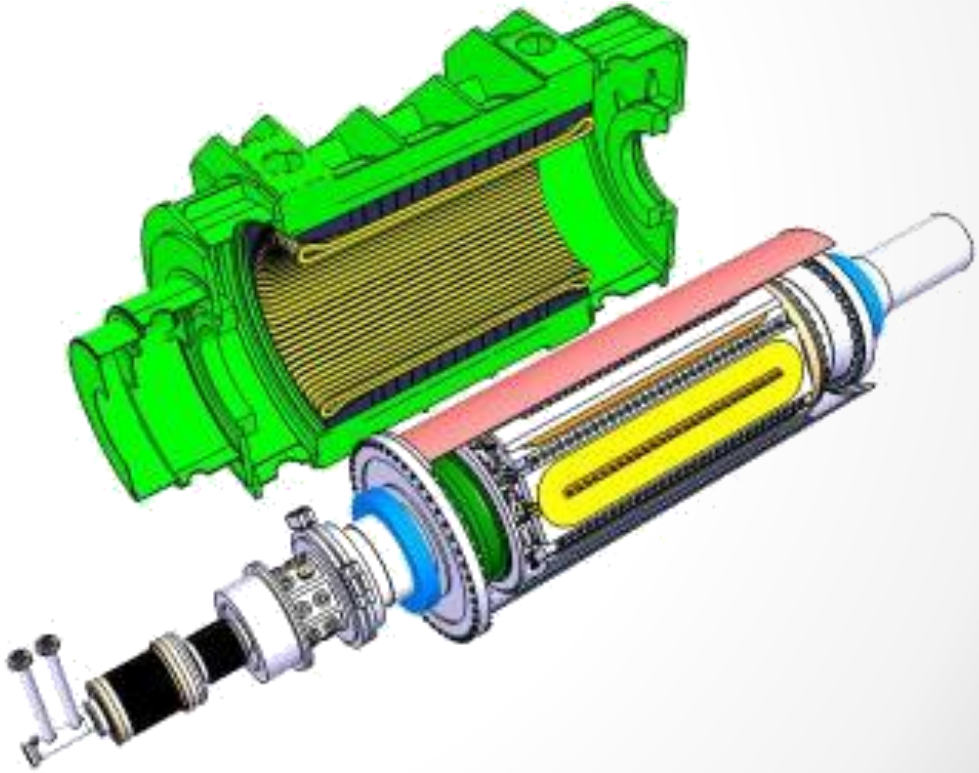
- Requirements for commercial ship propulsion
  - High efficiency
  - Compact
  - High reliability
  - Low cost

- Developed a 1 MW HTS motor and a 3MW HTS motor
- Demonstrate high efficiency, high output density, and reliability
- Enhance the HTS motor design technology to further promote the commercialization
- **Loss Analysis** Improve the loss prediction method

3 MW HTS motor

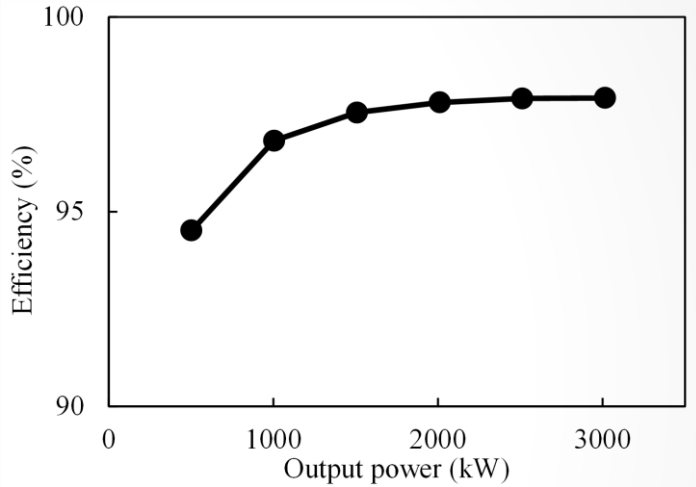
- Radial-type field-winding synchronous motor
- HTS field coil
  - Coreless racetrack type
  - Cooling by Helium gas
- Armature coil
  - Copper wire winding
  - Nonmagnetic teeth
  - Cooling by air

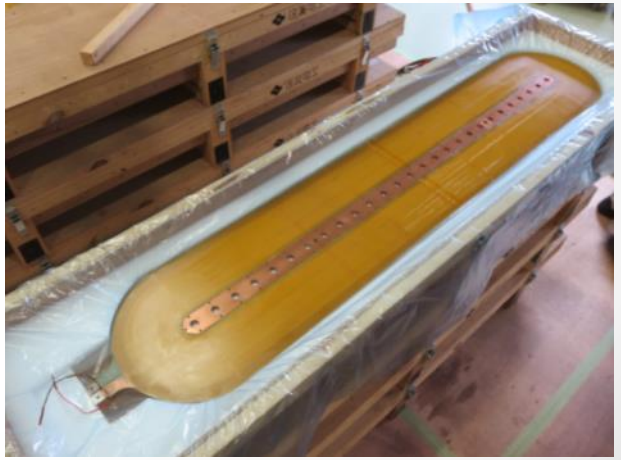
Rated speed	160 rpm
Number of poles	6
Field coil windings	DI-BSCCO
Maximum field coil temperature	30 K
Dimensions	D 1.4 m×L 2.8



Test result

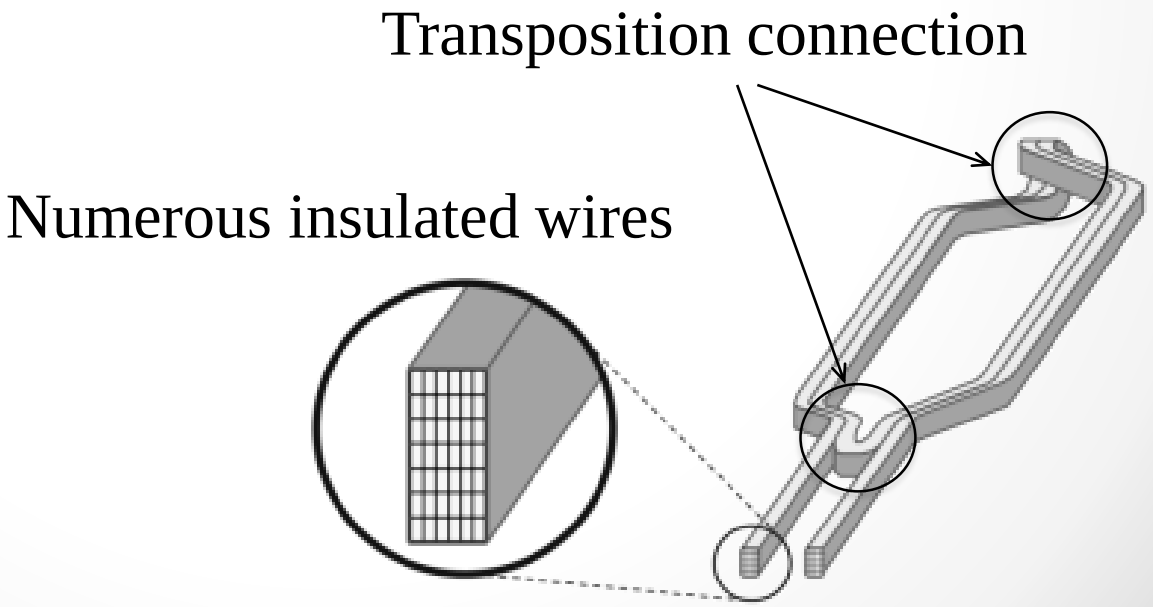
- Performance Test
  - measure the efficiency
    to draw a motor efficiency map
- 100-hour Endurance test
  - AT rated power of 3 MW
- Variable-load Test
  - Simulate an emergency maneuver
- Track record
  - Total operating hours at 3 MW: 106 H
- Inspection
  - Take the motor apart and inspect





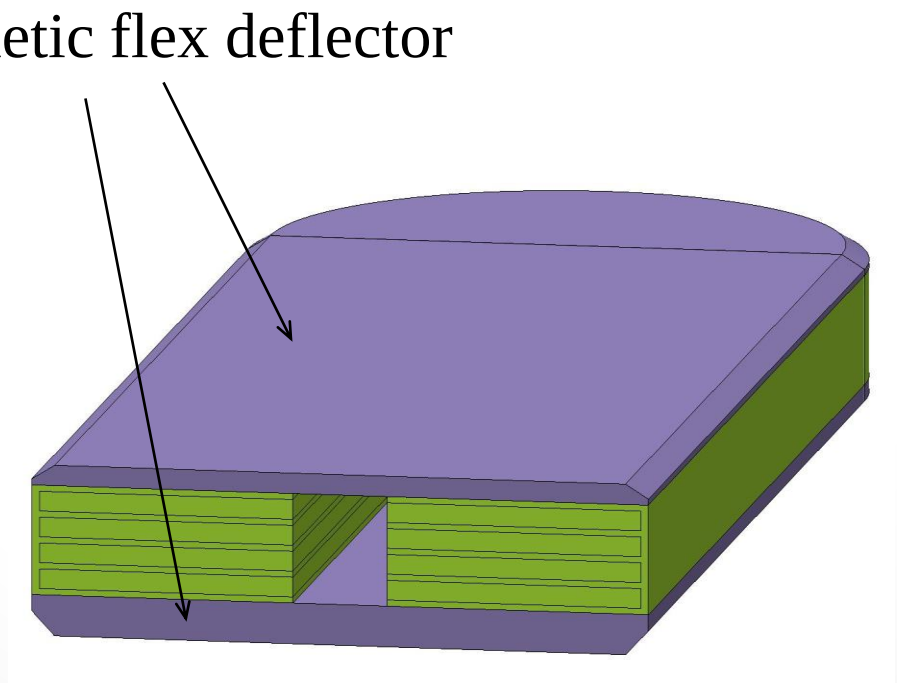
Design of armature coil

- Numerous insulated copper wires
- Transposition winding
- Nonmagnetic teeth



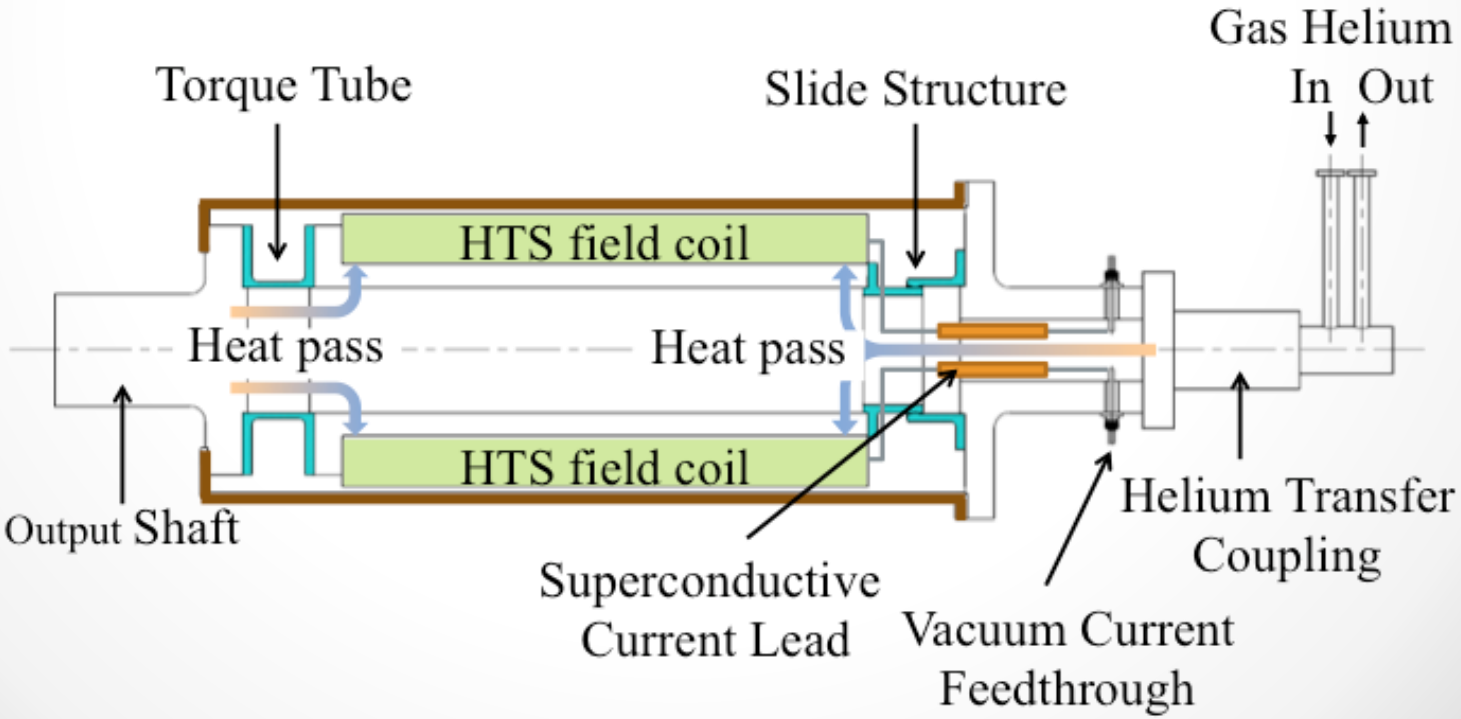
Design of HTS field coil

- Racetrack type with nonmagnetic core
- Magnetic flex deflector (MFD)



Design of rotor structure

- Nickel-based superalloy torque tube
- FRP slide structure
- HTS current lead

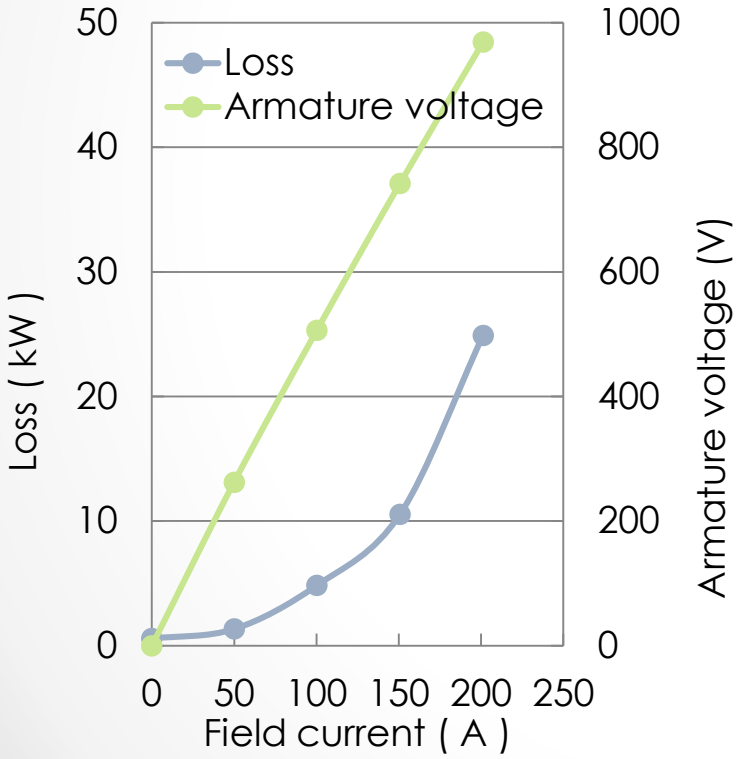


Details of the analyzed loss

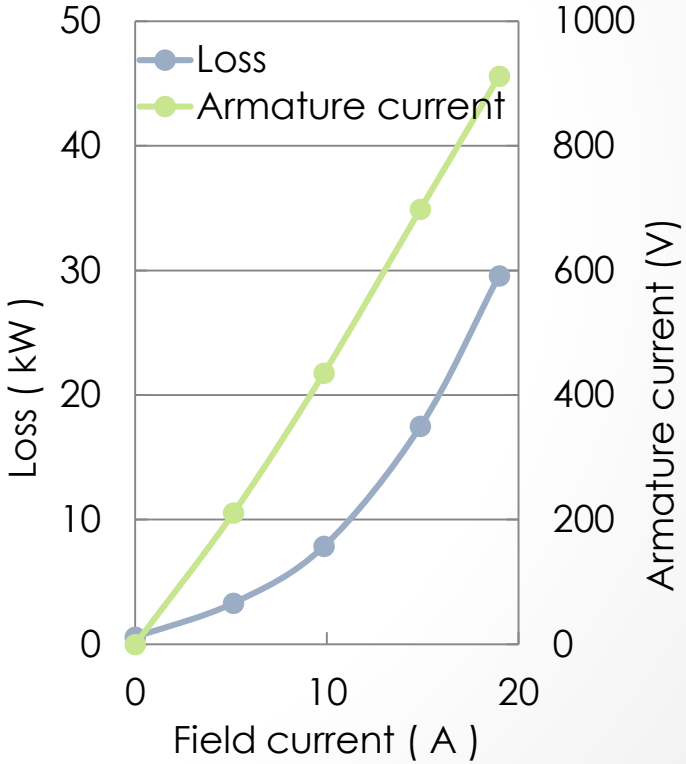
Friction and windage loss	
Iron loss	
Armature loss	Joule heating loss
	Individual wire eddy current loss
	Circulating eddy current loss
Cooling loss	HTS field coil heating loss
	Joule heating loss
	Thermal conduction loss
	Heat leak loss
	Radiation loss, etc.
Others	Stray load loss, etc.

Open- and short-circuit test

- Estimate the friction and windage loss and the stray load loss



Open-circuit test result

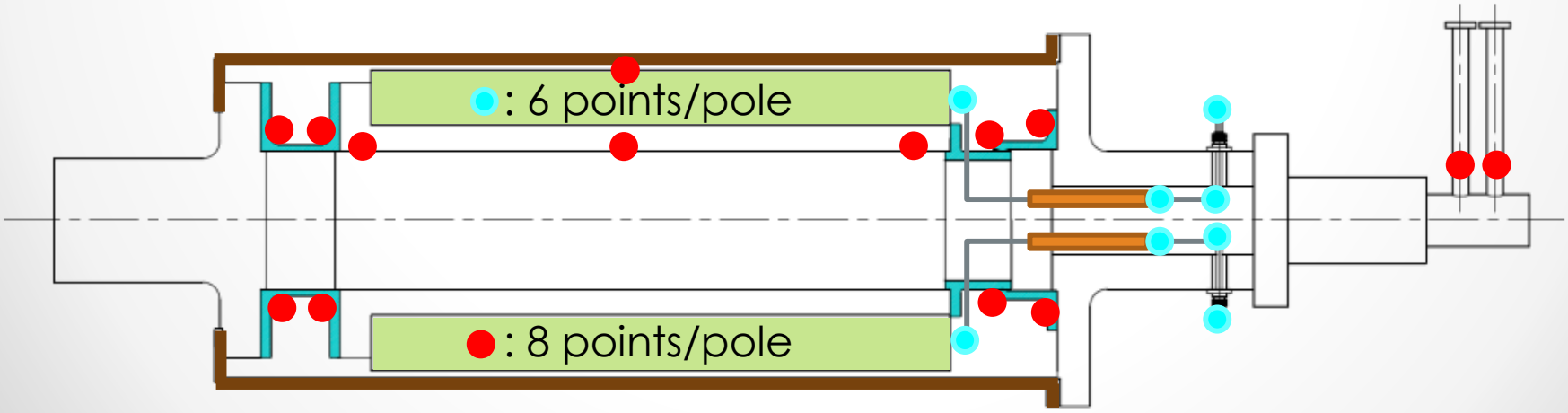


Short-circuit test result

Non-rotating test

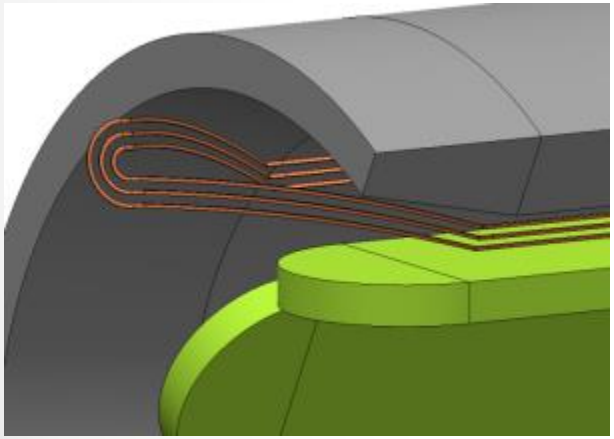
- Measure temperatures and voltages inside the rotor in order to accurately break down the cooling loss
- Measuring points
  - Temperature at 65 Points
  - Voltage at 41 points
  - Current at one point

● : Temperature
● : Voltage

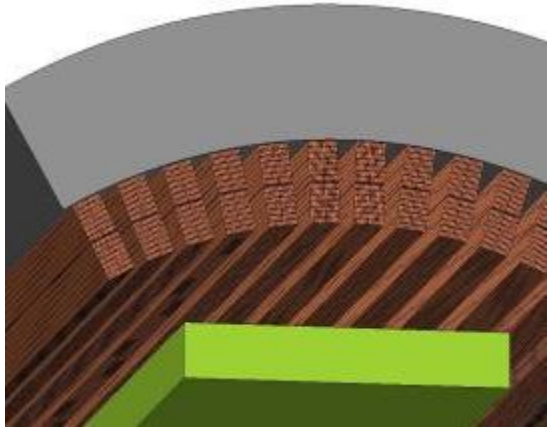


Electromagnetic Analysis

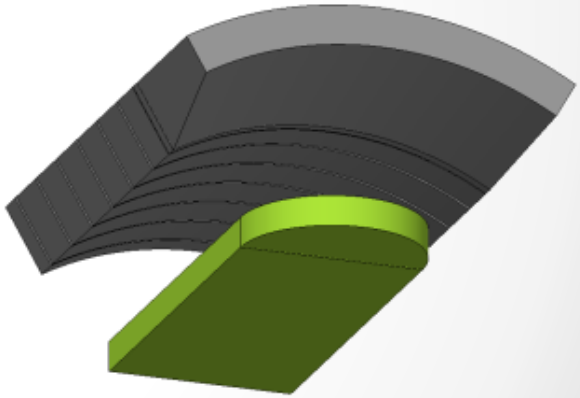
- Estimate the individual wire eddy current loss,
  the circulating eddy current loss, and the iron loss



Individual wire
eddy current loss

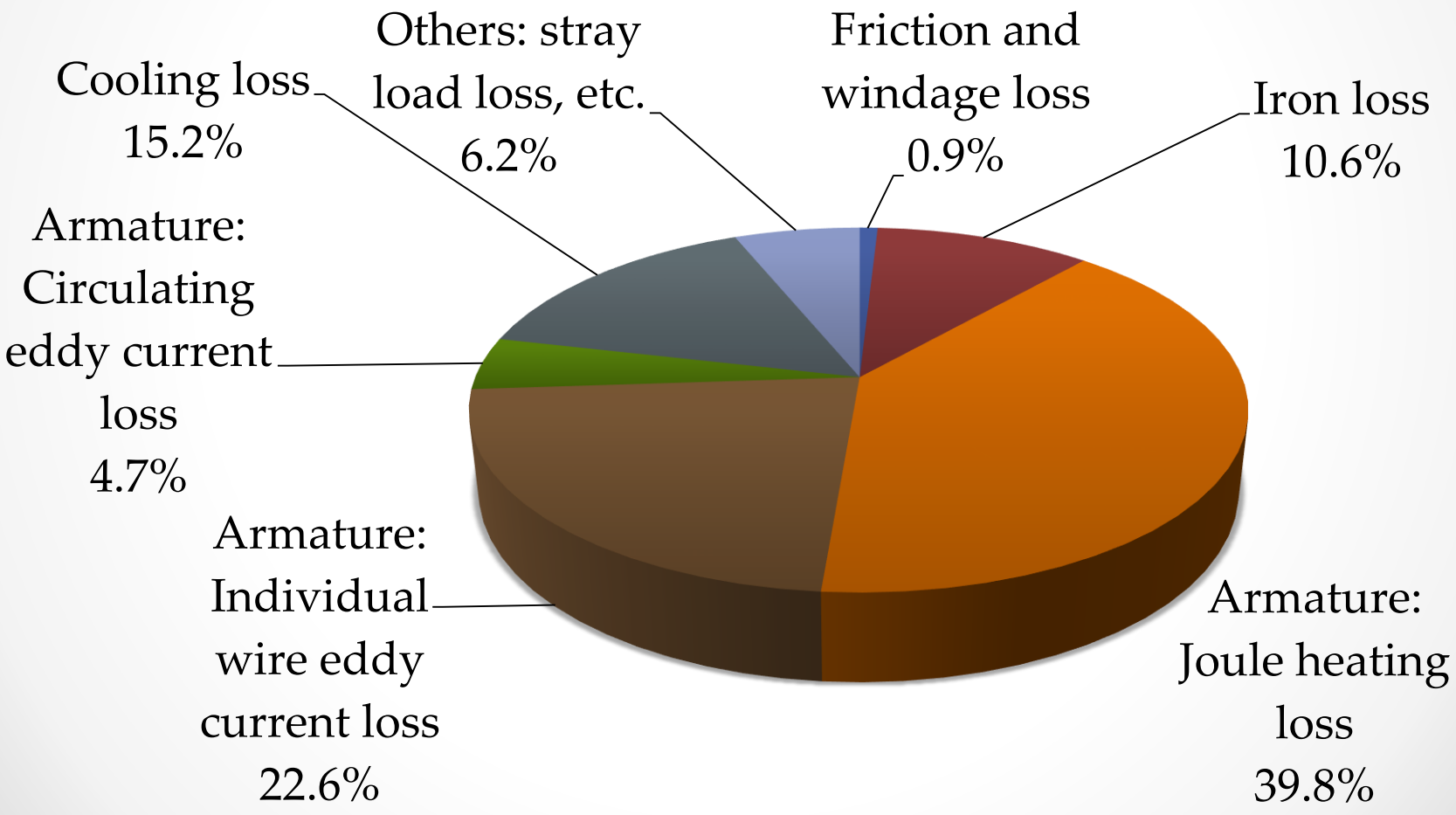


Circulating
eddy current loss

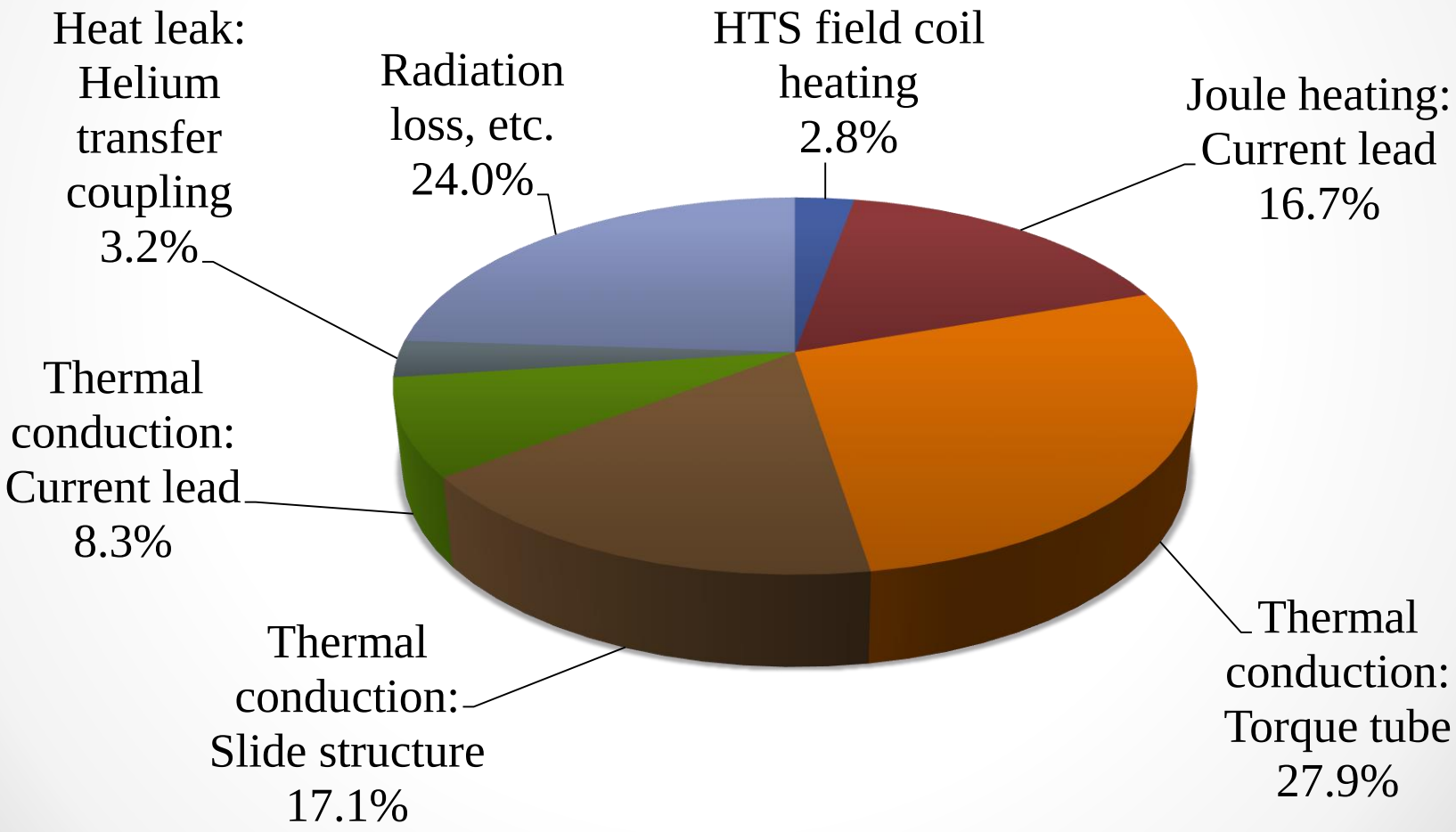


Iron loss

Details of loss at 3 MW



Details of cooling loss



Conclusion

- The loss was accurately broken down.
- The results close to those expected were obtained.
- The high efficiency design worked well.
- The accuracy of the loss prediction method was improved by this work.