Coolant Transfer Coupling with Integrated Dynamo for Rotor with HTS Windings

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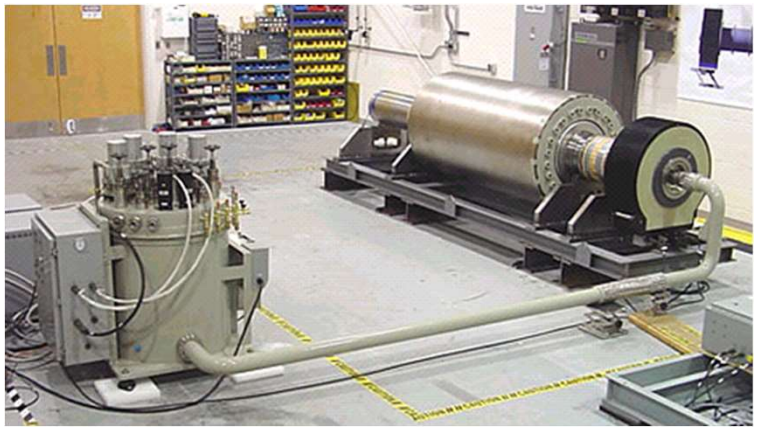
Coolant Transfer Coupling for HTS AC Machines

OUTLINE

- HTS machine configuration
- Features of coolant transfer coupling
- Coolant transfer coupling concept
- Brushless dynamo exciter concept
- Dynamo excitation of field winding
- Dynamo integration with transfer coupling

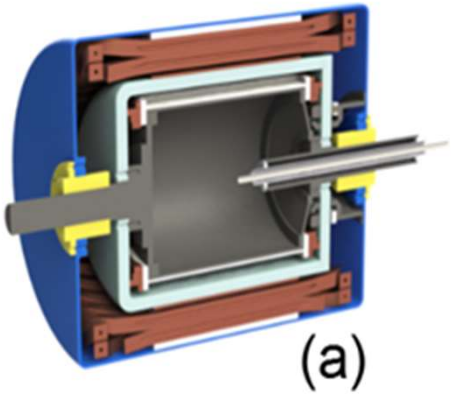


Courtesy AMSC

Reliable means for transferring coolant and excitation power to the rotating HTS field winding are highly essential for aircraft applications

Superconducting (SC) Machine Configuration

- Majority of machines are synchronous type employing SC for the DC field winding
- Until the nineties, most machines were built with NbTi (low temperature superconductors – LTS)
- Nineties onwards, High Temperature Superconductors (HTS) became favorite
- Majority of the SC machines have DC excitation winding on the rotor
- In a few applications, DC excitation winding is on the stator and rotor carries AC armature winding

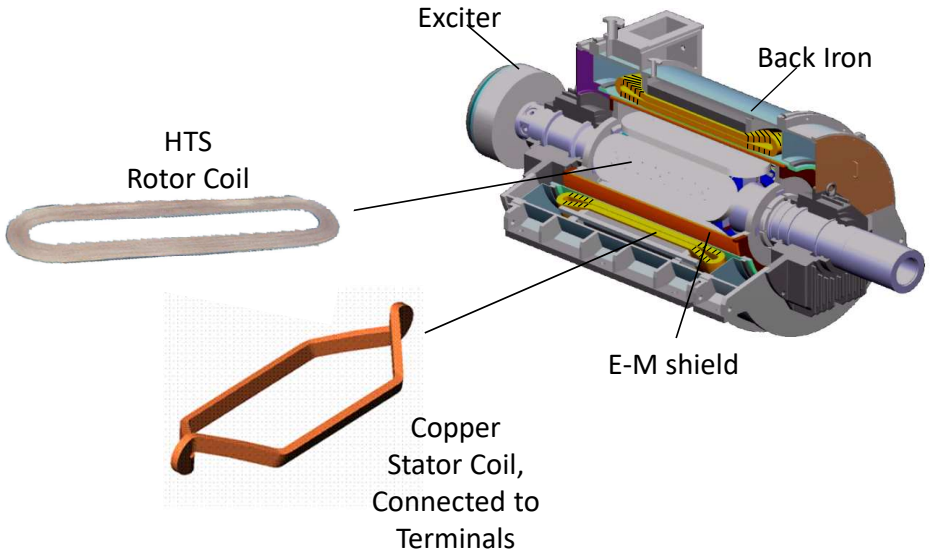


Only HTS based machines are discussed in this presentation

Key Components of HTS Rotating Machines

It is preferable to employ individual rotor and stator vacuum enclosures for ease of;

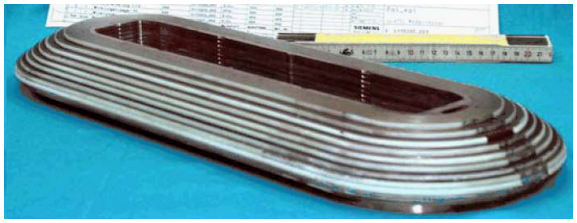
- Manufacture
- Assembly
- Testing
- Maintenance



Most commonly used configurations: HTS field winding and Copper armature winding

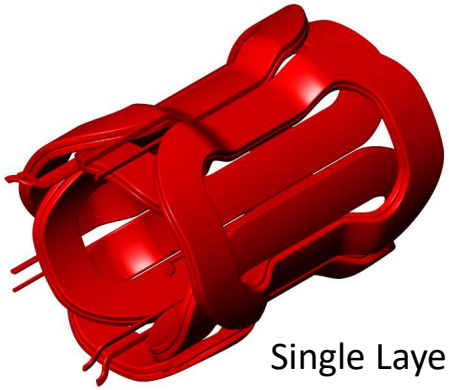
5000 HP Motor Rotor and Stator Details

- Field Winding - pancake BSCCO-2223 coils
- Field Coils - Conduction cooled with liquid neon
- Closed-loop cooling system used G-M cryocooler cooler
- Armature Winding – Innovative Single layer copper coils
- Copper coils cooled with fresh water
- Met all performance expectations



Field Coil

Courtesy AMSC



Single Layer Stator

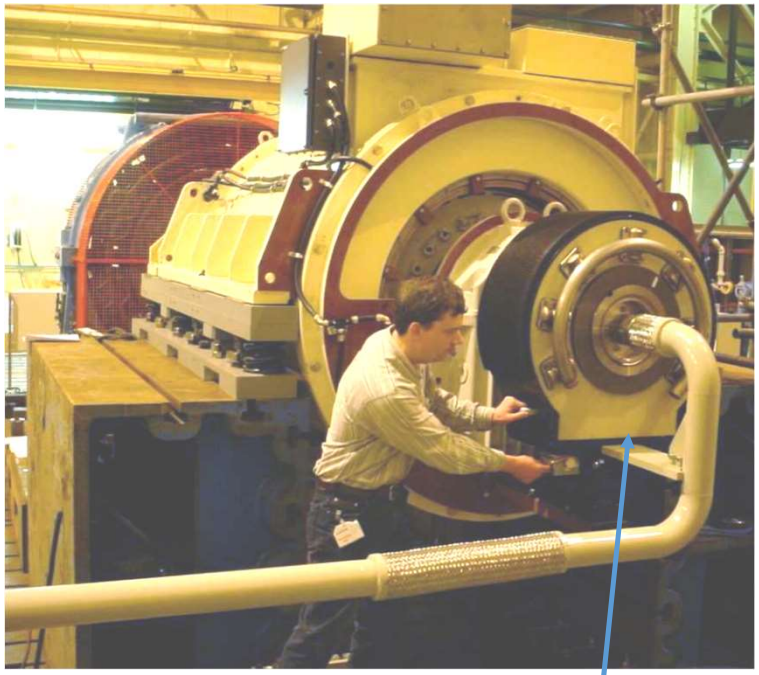
Largest rating machine built at 1800 RPM to date

5 MW, 230 RPM Motor Assembly

- Superconducting motor is shown undergoing factory testing
- Coolant is supplied to the rotor in a closed loop fashion

Ref: J.F. Maguire, P.M. Winn, A. Sidi-Yekhlef and J. Yan, 'Cooling System for HTS Machines',

US Patent # 6,625,992 B2, September 30, 2003



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Coolant Transfer Coupling

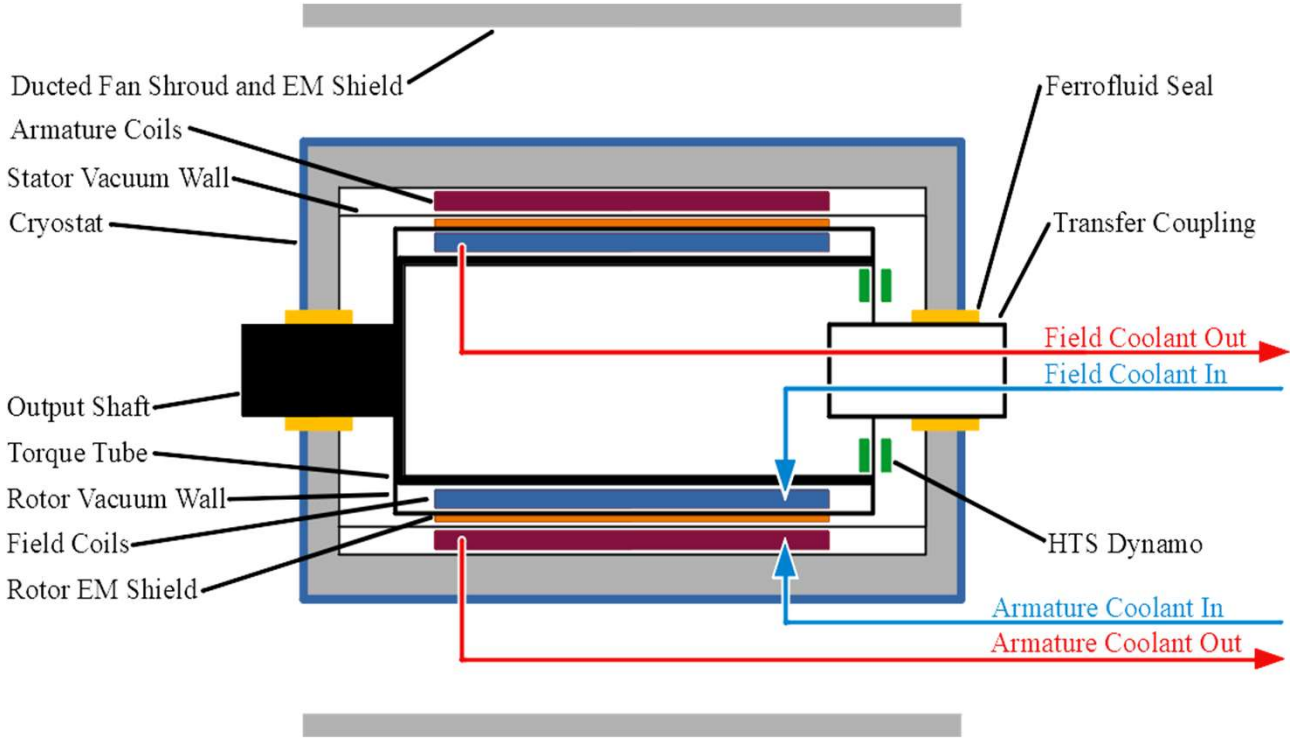
Motor was successfully tested - results were consistent with the design values

Features of Coolant Transfer Coupling

- Cool rotor windings with coolant supplied from a stationary source to the rotor with rotary couplings
- Closed loop gaseous helium couplings employed on mega-watt size machines operating at both low speed and high speed
- Some couplings experienced leakage of cryogen out of the closed loop - needing periodic replenishment
- The cryogen leakage highly undesirable for HTS machines for the aerospace applications
- The concept presented here prevents the cryogen leakage and/or enables collection of leaked coolant to the closed cooling loop
- HTS dynamo is also integrated for field excitation wirelessly, i.e. without current leads
- These concepts need de-risking before using in the motors and generators for the aerospace applications
- Possible cryogens for cooling include gaseous helium, Neon, H2 and N2.

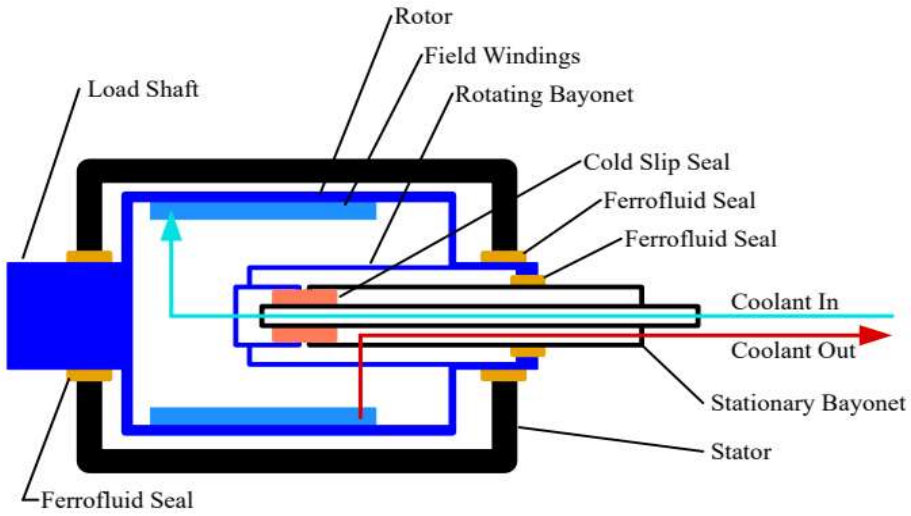
Reliable transfer coupling with integrated dynamo is essential for achieving highest power density and efficiency

Synchronous Machine Concept for Aircraft



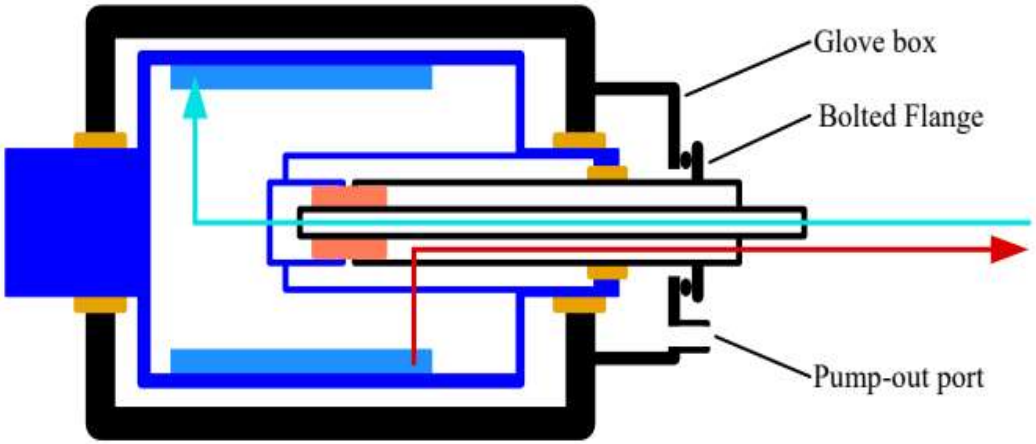
Concept shown has superconducting windings both on rotor and stator

Coolant transfer to rotor – Mod A1



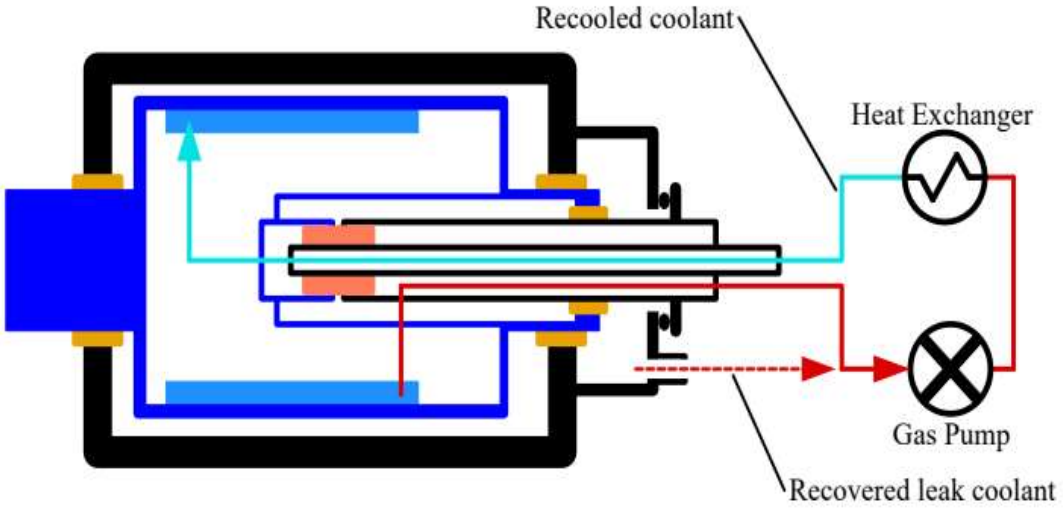
- Rotor assembly with a slip-seal coupling with stationary coaxial tubes mating with rotating components
- Returning coolant is sealed with a Ferro-seal at room-temp.
- The Ferro-seal is not very effective in preventing leakage of the coolant to the environment

Coolant transfer to rotor – Mod A2



- Coolant supply end is enclosed in a glove-box type structure
- Pump-out port is included to handle any leaking coolant
- Any leaked coolant out of the transfer coupling is collected and returned to the closed loop
- Alternatively, a positive pressure on the port prevents leakage

Coolant transfer to rotor – Mod A3

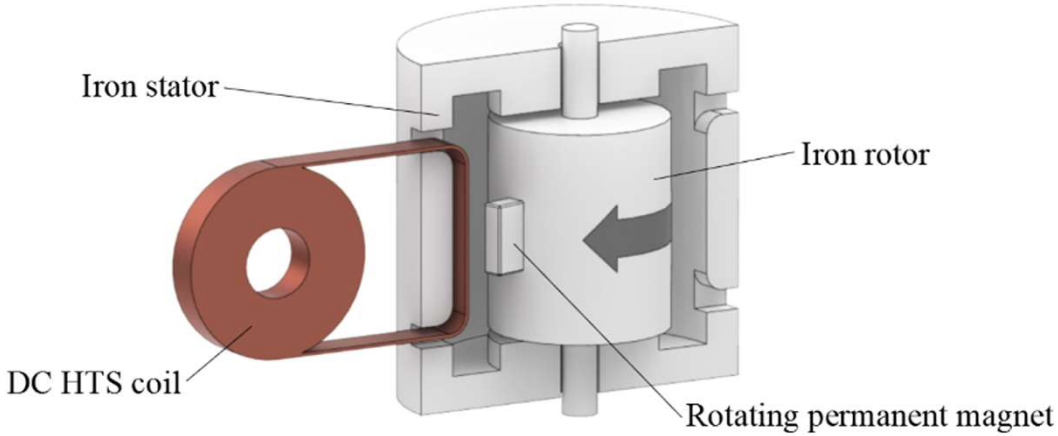


- A possible coolant loop is shown
- Coolant circulated in the closed loop with a gas pump
- Leaked coolant transferred to the closed coolant loop

This coolant transfer system needs to be demonstrated for use in airplane machines

HTS Dynamo Concept

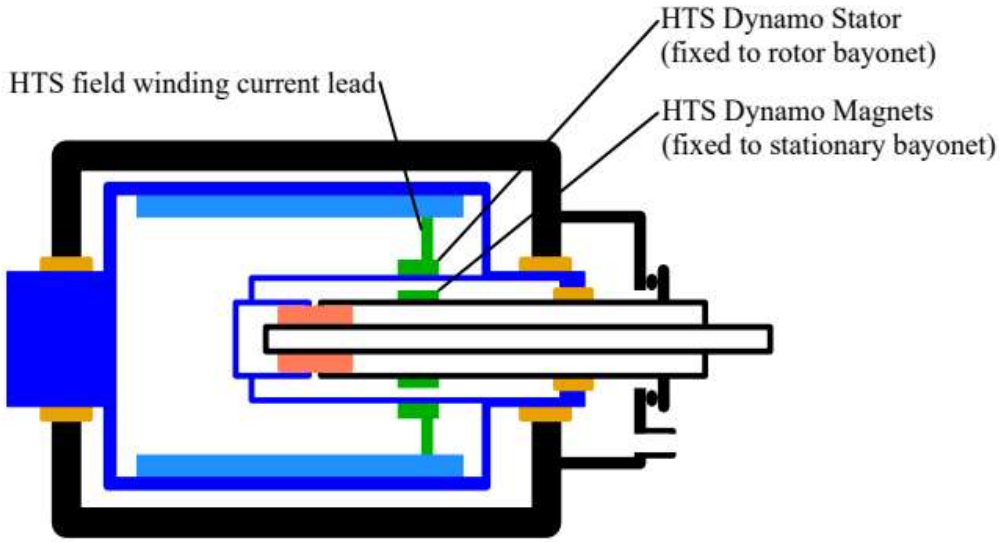
- Field coils excited wirelessly for minimizing thermal conduction into cold environment
- Brushless exciter (Dynamo) shown here accomplishes this
- Dynamo exciter could operate at currents > 1 kA
- Plans are to integrate it with the coolant transfer coupling



This dynamo concept has been successfully built and demonstrated by RRI-VUW

Synchronous Machine Concept for Aircraft

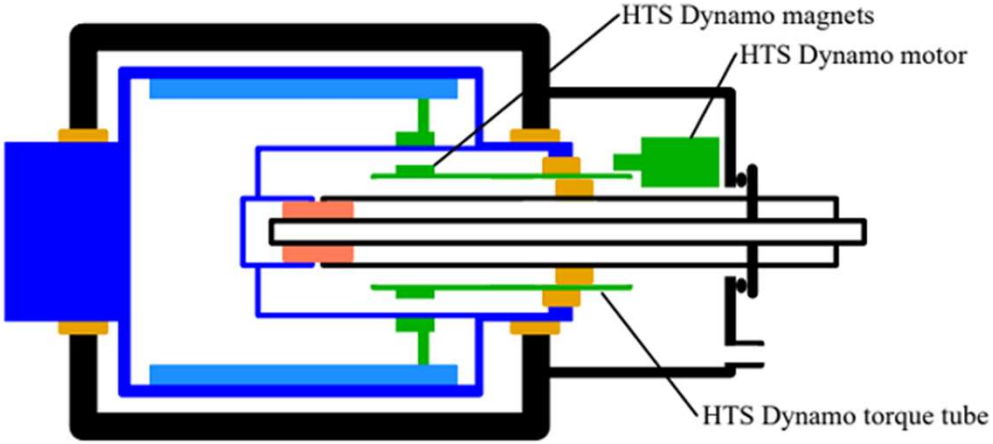
- Dynamo integrated into the coolant transfer coupling
- PMs are carried on the stationary tube of the transfer coupling
- Dynamo HTS rotating component, with induced DC voltage, connected to the superconducting field winding



This arrangement excites field coils wirelessly

Coolant transfer to rotor – Mod A5

- Field poles may require charging prior to starting the machine sometimes
- PMs are attached to the rotatable outer tube of bayonet
- Outer tube is rotated with a motor located in the glove box
- Motor could be stopped once poles are charged
- Motor rotating speed could be varied or reversed, as necessary, for adjusting the field current



Conclusions

- The rotary seal concept facilitates transfer of coolant from stationary source to the rotor for cooling the field winding
- Proposed system captures leaked coolant and returns it to the closed loop cooling system
- An HTS dynamo incorporated in the coolant transfer system charges field coils wirelessly
  - without current leads spanning room-temperatures and cold environment
- Leak-free transfer coupling with integrated dynamo is highly desirable for achieving highest possible power densities (kW/kg) and efficiency for airplane applications

Questions