5LH08

# Conduction Cooling of a Compact HTS Motor for Aeropropulsion

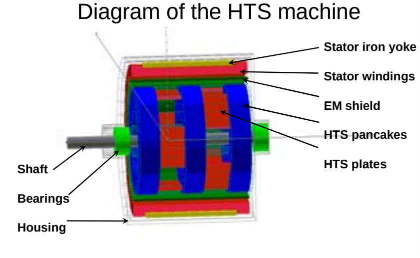
Jules E. Pienkos, Philippe J. Masson, Cesar A. Luongo

Center for Advanced Power Systems
FAMU-FSU College of Engineering
2000 Levy Avenue Building A
Tallahassee, FL 32310
pienkos@caps.fsu.edu

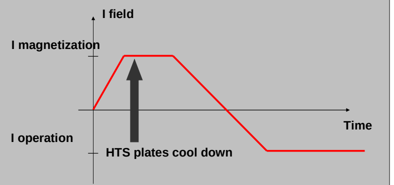
Thermal aspects of a novel high temperature superconducting (HTS) motor design are examined for use in the propulsion of an aero-vehicle. To simplify the refrigeration, focus is on conduction cooling of the superconducting material directly from the cold head of a cryocooler. The motor description and conduction apparatus are shown. A model has been developed and the results are presented. An experimental setup has been developed to validate the system model. The goals of this study are to show conduction cooling viable for an HTS motor, steady state operation heat loads can be limited and transferred away from the HTS components, transient cool down is studied, and flux trapping in the bulk material plates is possible as required by the motor design.

## HTS Motor Design

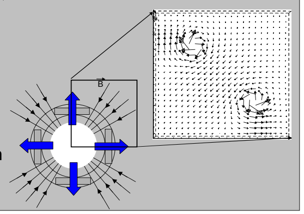
Diagram of the HTS machine



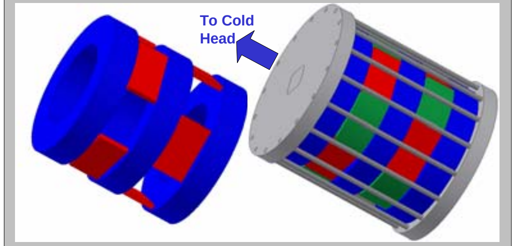

Flux trapping and 2-step cooling is needed and studied thermally




- 8 poles
- 4 poles come from trapped flux
- 4 poles come from shielding/concentration
- very high flux density

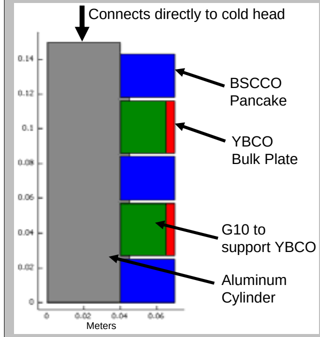


## Cooling Design




The conduction cooling apparatus is designed to connect a cryocooler directly to the HTS motor. The BSCCO pancakes are wound directly to the conduction apparatus, and the bulk YBCO material plates are supported by G10.

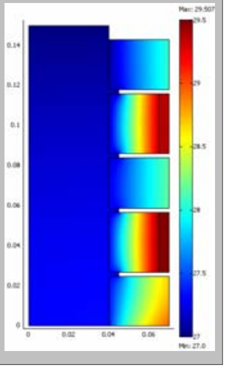
## Simulation Results – Steady State




Cross section of the conduction apparatus and HTS components

Steady state operation is designed maintain the operating temperature of the HTS materials (30 Kelvin). The cryocooler provides a refrigeration load at the cold head which connects directly to the conduction apparatus. Direct conduction cooling avoids use of liquid cryogen baths which can be problematic for mobile applications. The use of MLI wrapped around the system reduces the radiation heat load.

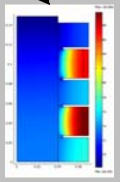
The results on the right provide the temperature profile during steady state operation. The temperature gradient is only a few degrees and the hot spots on the HTS components are under the operating temperature. The heat loads on the system are a radiation load of ~ 23 W/m² and an equivalent resistance load on the pancakes of 0.6 Watts each. Note that the contact resistance is not taken into account in this simulation, but will be considered with the highest priority in construction of the HTS motor and conduction apparatus.

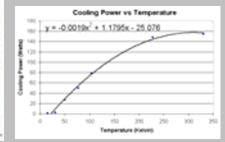


## Simulation Results – Transient

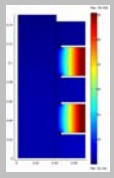
90 minutes — 130 minutes — 135 minutes — 150 minutes — 155 minutes — 170 minutes

- Cool down from 300 K to 90 K
- Cool down BSCCO pancakes to 35 K, maintaining YBCO plates at 90 K
- Ramp up current in BSCCO
- Stop heat to YBCO, cooling system to 40 K
- Ramp down current
- Cool system to S.S operation

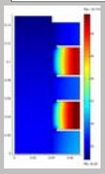





The initial temperature of the entire system is 300 Kelvin, the cryocooler head is then attached to the conduction apparatus. The cold head refrigeration power is a function of temperature and for the simulations, the plot above was used.

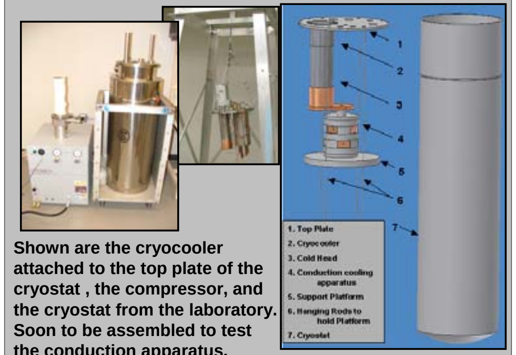


To achieve the strongest magnetic field, the current in the pancake must be at maximum while the bulk plates are still above the critical temperature.

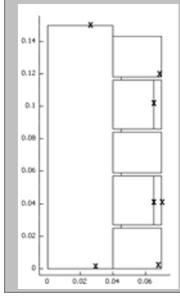


After the current in the BSCCO pancakes is at max and the bulk plates are cooled, the current is ramped down to stabilize the magnetic flux in YBCO plates.

## Experimental Apparatus




Shown are the cryocooler attached to the top plate of the cryostat , the compressor, and the cryostat from the laboratory. Soon to be assembled to test the conduction apparatus.



The experimental mock up will be fitted with thermocouples, locations shown on the diagram to the left, to measure the temperature gradient of the conduction apparatus and the HTS components. The transient temperature must also be known to control the bulk material plates at 90 K to ensure that the flux trapping can occur and to verify the simulation results. Contact resistance will be kept at a minimum in construction to enable the most efficient heat transfer from the cryocooler.

## Conclusions

- Simulation results show that providing effective cooling to the HTS components using direct conduction cooling is viable
- Steady state heat loads are manageable by insulation and design
- Transient behavior including cool-down time and flux trapping using heaters, thermocouples, and conduction cooling is possible shown by simulations performed
- Construction is key to enabling a working thermal motor mock-up,
- An emphasis on contact resistance is needed
- Model will be validated by experimental values

University Research Engineering Technology Institute (URETI) on Aeropropulsion & Power Technology (UAPT)

Florida A&M University - Florida State University
College of Engineering