GE Microwave Blade De-Icing - Test

THE DESIGN LAB at Rensselaer

Brian King (MATL), Brian Latwis (EE), Colleen Morris (MECL/DIS), Victoria Ruplin (MECL), Elizabeth Veillette (MATL), and Litao Zhao (MATL)

Customer and Objectives

GE Power and Water

1. Create a test environment to quantify **susceptor material** microwave absorption efficiency and ability to melt ice from wind turbine blade samples.

2. Execute **finite element analyses** to simulate ice phase change for susceptor materials and to aid in determination of susceptor efficiency.

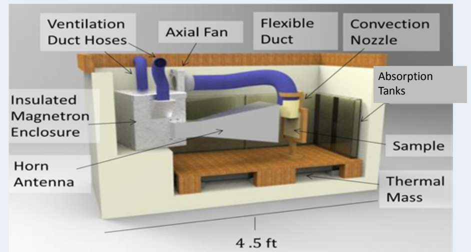
Background – Spring 2016

Achievements

- Ice melted from sample

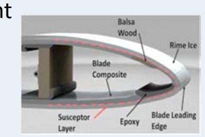
Areas for Improvement

- Inaccurate temperature and power density measurements
- High reflections in test chamber
- Few susceptors tested
- Thermal gradient in test chamber



Sub Systems

1. Materials Selection
2. Temperature and Power Density Measurement
   a. Thermistors
   b. IR Camera
3. Freezer Thermal Management
   a. Magnetron Cooling
   b. Thermal Transient
4. Finite Element Analysis



1. Susceptor: Material Selection

G10/FR4 & Ice are relatively transparent to microwave radiation.

Resistive Heating: Electric field creates bulk resistance and heat

- Susceptor (popcorn) film, carbon fiber, carbon nanotubes

Dielectric Heating: Dipole bond vibrate in an electric field

- Carbon nanotubes, MF-500, carbon fiber

Magnetic Heating: Ferromagnetic materials vibrate in a magnetic field causing heating

- MF-500, MAST and Laird Films

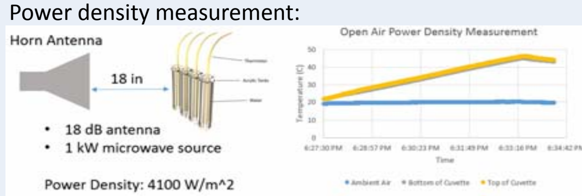
MF-500 | Susceptor Patch | Carbon Nanotubes

Absorber:		Substrate:			
Material:	Thickness (in):	Material:	Thickness:	L x W (in x in):	Test:
MF-500	0.02	G10-FR4	1/16 in	5.6 x 5.6	Open Air, De-Ice
10, 25, 40, 55 wt % CNT in water based Polyurethane	0.02	G10-FR4	1/16 in	5.6 x 5.6	Open Air, De-Ice
17 wt% CNT in PDMS, polyester, and epoxy	0.02	G10-FR4	1/16 in	5.6 x 5.6	Open Air, De-Ice
Popcorn film	0.03	G10-FR4	1/16 in	5.6 x 5.6	Open Air, De-Ice
15 wt% CNT in Low Viscosity Epoxy	0.02	G10-FR4	Blade	6.8 x 4.8	De-Ice
Popcorn film	0.03	G10-FR4	Blade	6.8 x 4.8	De-Ice

2. Temperature Measurement

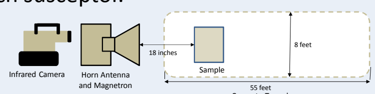
Thermistors

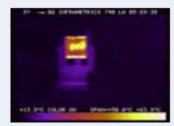
Power density measurement:



Infrared Camera

Open air testing to reduce the effects of microwave reflections. Temperature vs. Time plots extracted from infrared video for each susceptor.

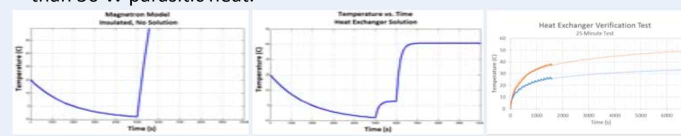




3. Freezer Thermal Management

Magnetron Cooling

- Maintain temperature below 40C, no condensation, isolate enclosure to less than 50 W parasitic heat.

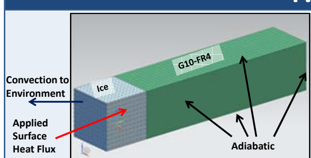


- Solution: Fanned 1500 Btu/h, 2gpm heat exchanger mounted within magnetron enclosure maintains temp at 35 C with 45 W parasitic loss.

Freezer Thermal Transient

- Reduce impact of microwave power on ambient temperature within freezer. Need to keep temperature below 0 C.
- Use ethylene glycol absorption tanks to increase thermal transient.
- After modifications, average ambient temperature at -4°C from -16°C starting T, well within desired range.

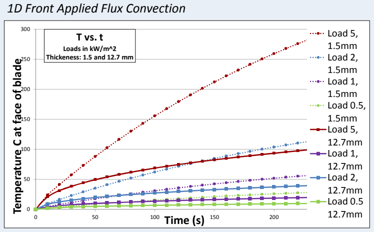
4. Finite Element Analysis

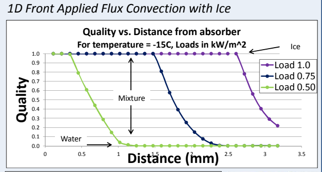


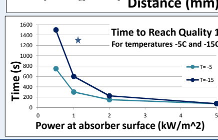
	Ice	G10-FR4
Density [kg/m^3]	916.2	1800
Thermal Conductivity [W/m-K]	2.22	0.288
Specific Heat Capacity [kJ/kg-K]	2.05	1
Latent Heat [kJ/kg]	334	-
Thickness [mm]	3.175	12.7 and 1.5

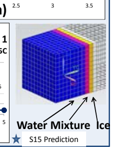
Objectives:

1. Evaluate surface temperatures for material testing
   1D Front Applied Flux Convection
2. Parametric evaluation of blade de-icing
   1D Front Applied Flux Convection with Ice





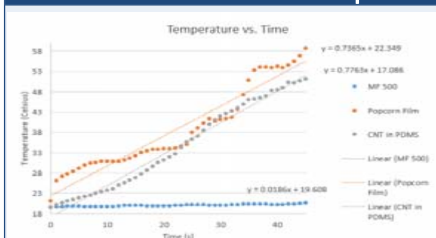


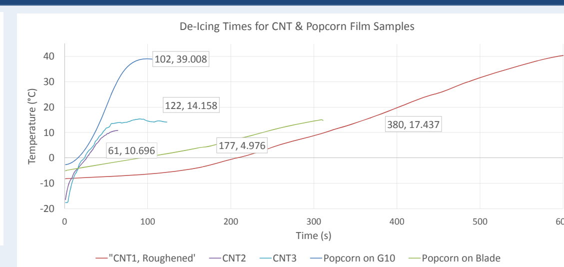


Analysis set-up:

Uniform initial temperature, Convection: $10\ W/m^2C$, NX Solver: NX Thermal/Flow

Susceptor Performance Results





Material:	Rate of heating (°C/min)
MF-500	1.1
Popcorn Film	44.2
17 wt% Carbon Nanotubes in PDMS	46.6

- Carbon nanotubes that were coated with paint showed de-icing times similar to those of the popcorn film.
- More testing could be done to verify results