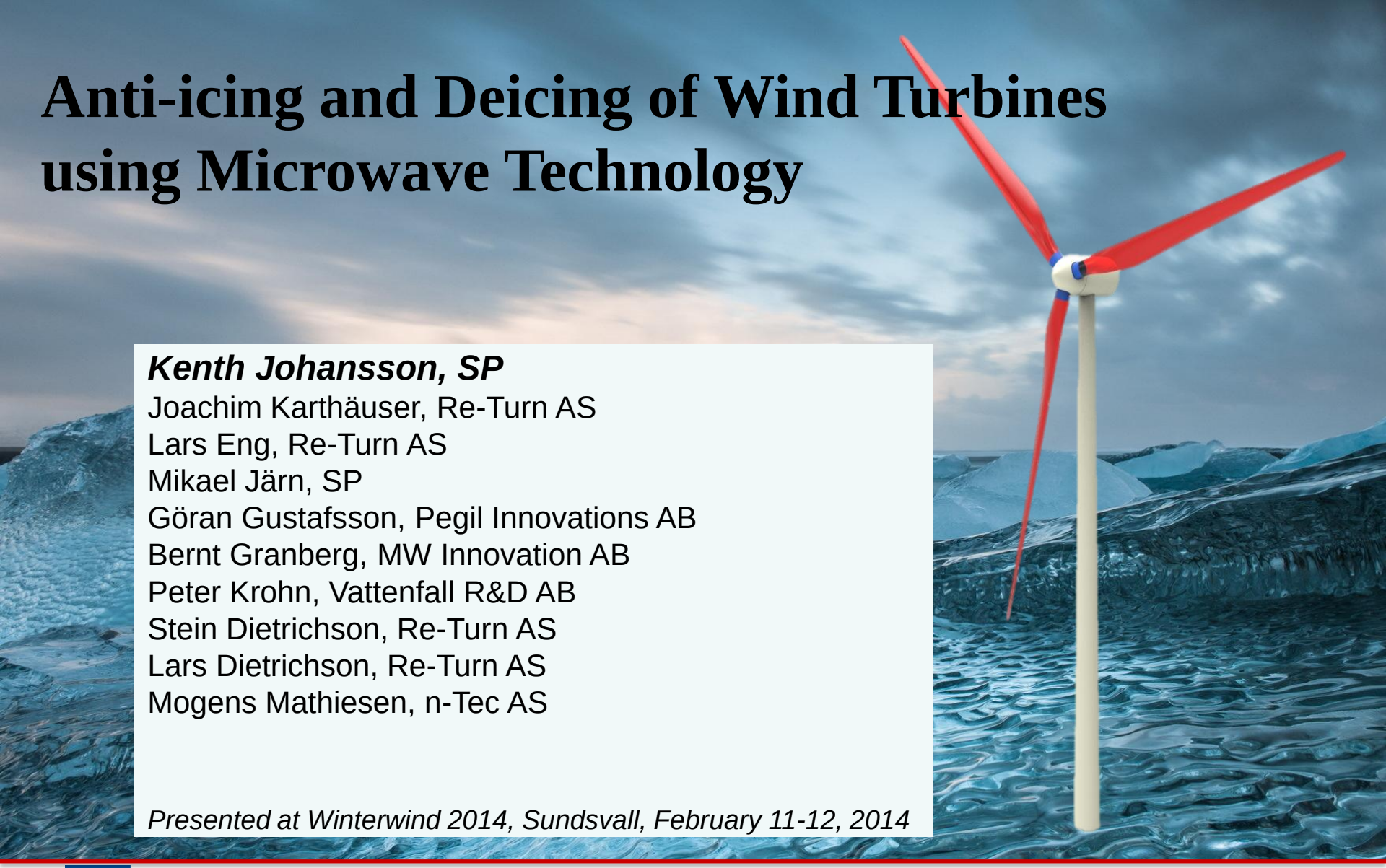
Anti-icing and Deicing of Wind Turbines using Microwave Technology



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Presented at Winterwind 2014, Sundsvall, February 11-12, 2014

SP Technical Research Institute of Sweden

Swedish Energy Agency

Presentation Outline

- Introduction to Microwave De-icing
- Micro-DeIce project
- Comparison with other de-icing methods
- Conclusions

Introduction to Microwave De-Icing

Microwave de-icing has been investigated in the past:

”Microwaves are much too inefficient to heat water or melt ice. Techniques involving direct microwave radiation towards water or ice on rotor blades should thus be avoided.”

“Heat conduction is also efficient and should be pursued. Using microwaves to heat the wing surface which then conduct heat to the water/ice is a very efficient and robust method.”

Quote from Vindforsk report Project 30988-1/V-238 (2008) (L. Bååth, H. Löfgren)

The “De-Ice” project, active deicing

- Cooperation between n-Tec and Re-Turn
- Total budget of 4 mio € in the period 2011-2015
- Supported by the Norwegian Research Council
- Based on patent applications
- Focus on two target areas:
  - (a) Chemical surface modification of carbon nano particles (CNP), incl. metallisation
  - (b) Design and production of composites containing CNP, for applications such as de-icing of wind power and marine installations (heating foils, microwave heating)

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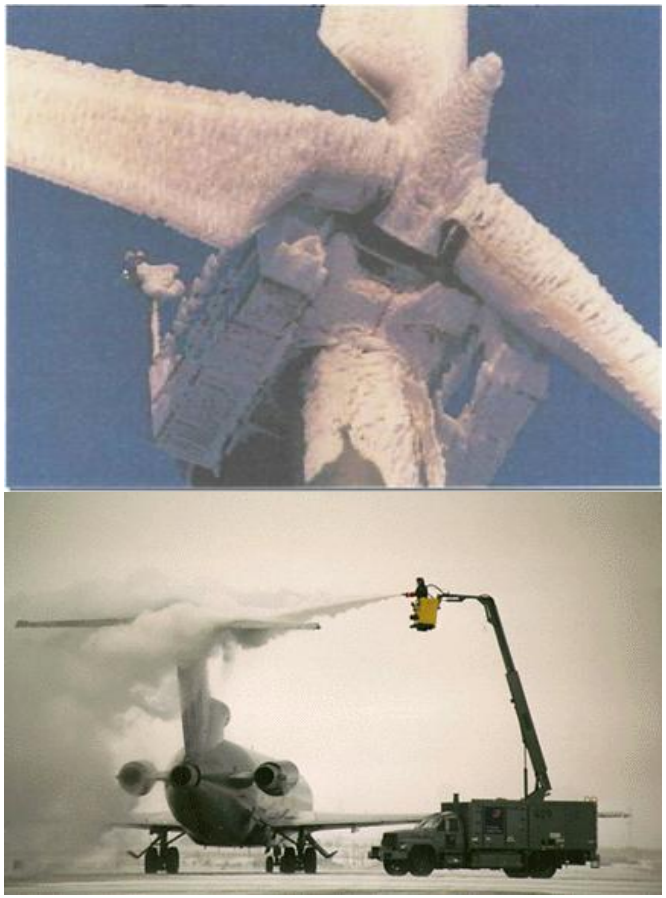


Re-Turn AS and n-Tec AS

Re-Turn: 10 employees, > 1 mio € turnover
Consultancy – R&D – Sales of thermosets – Design and testing of composites

Major projects: Marine coatings (spin-off AMC AS)
(2005-2010)
Eurostars project epoxy and PU gelcoats (2009-2011)
Off-shore CF composites (extreme chemical stability, high temperature) 2012-

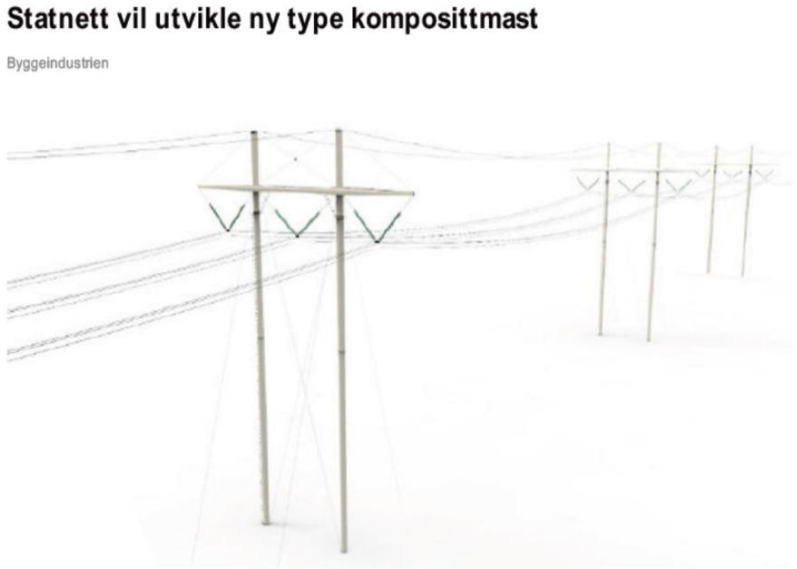
N-Tec: SME, part of Scatec AS portfolio

Production of special CNT and carbon particles

Joint projects Re-Turn AS and n-Tec AS:

HV composite masts for Statnett
2012-

DEICE:CNT modification and deicing products
2011-2014



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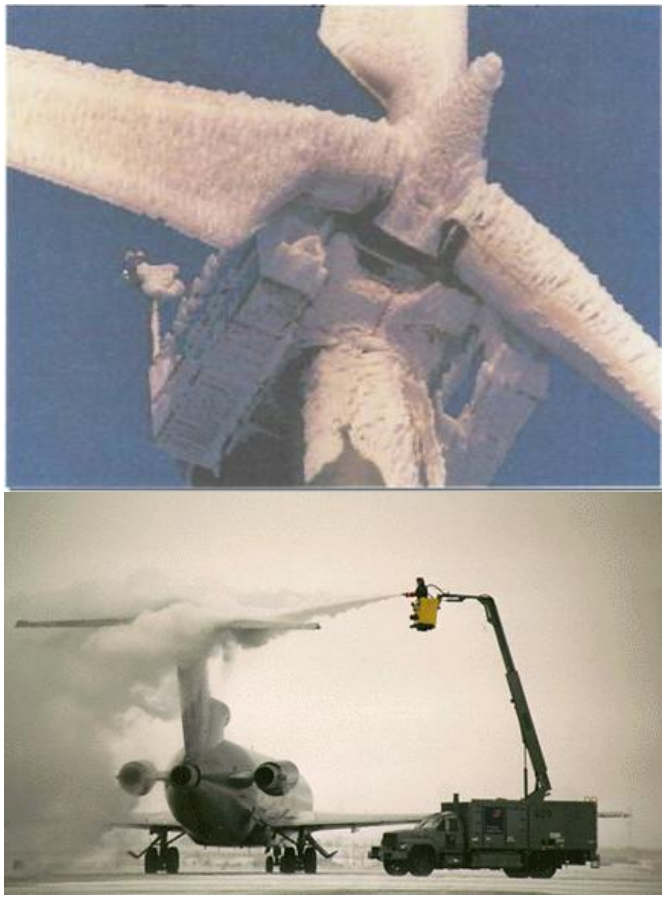
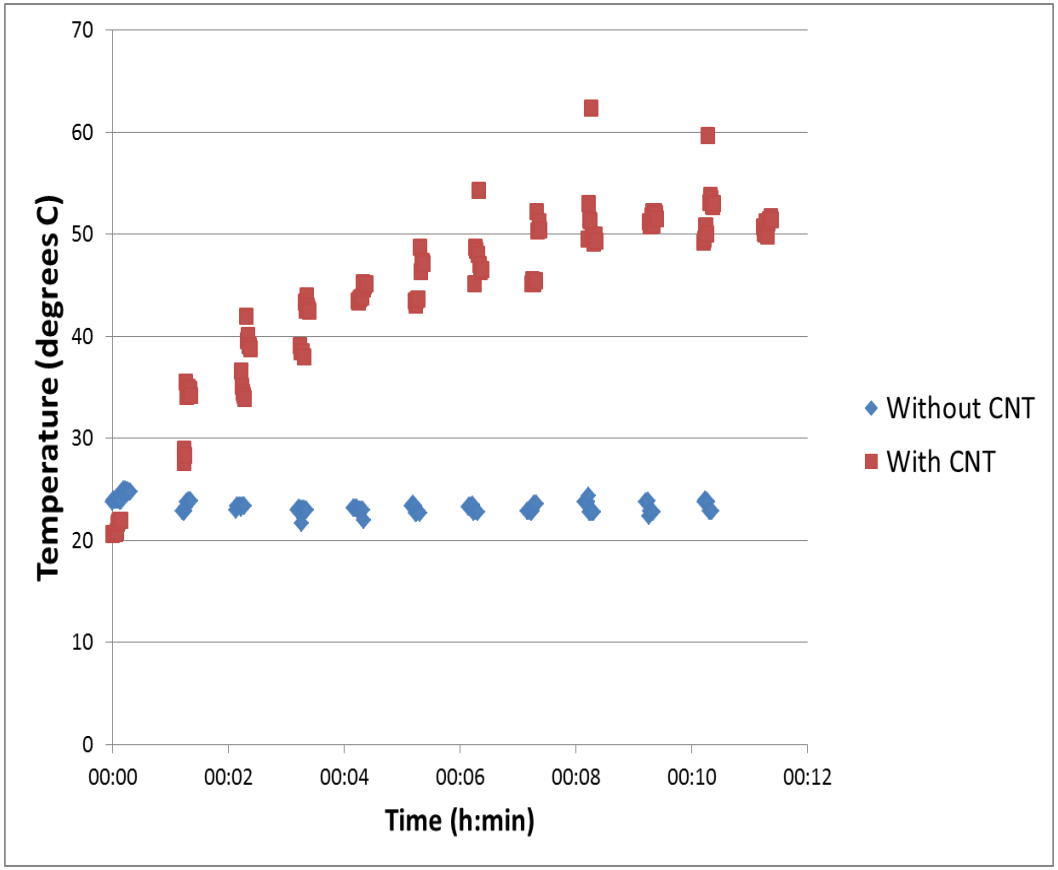


Effect of adding CNT particles to the coating

Microwave exposure of Polyurethane coating with and without CNT



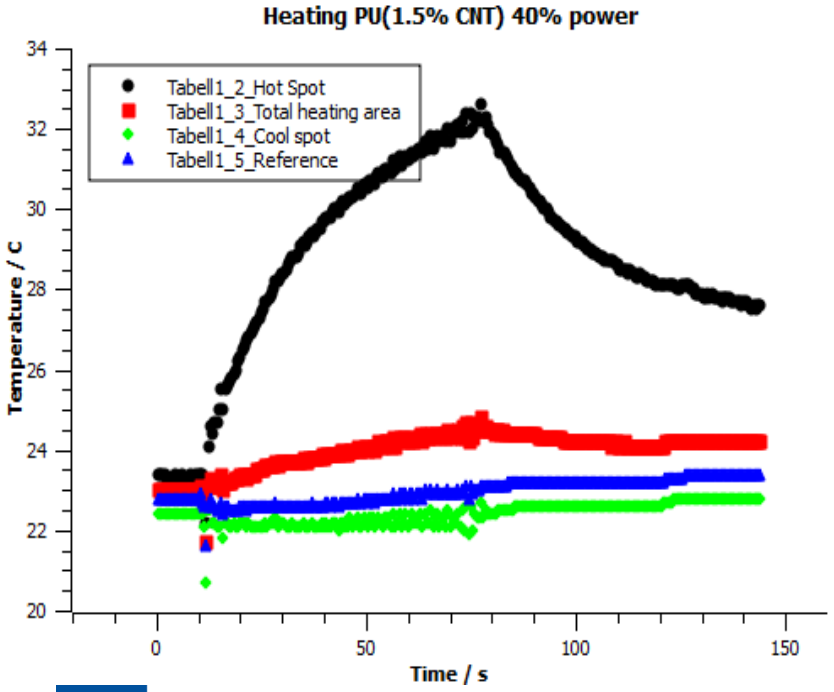
MW Exposure:
Max. power (900 W) for 3 sec per minute

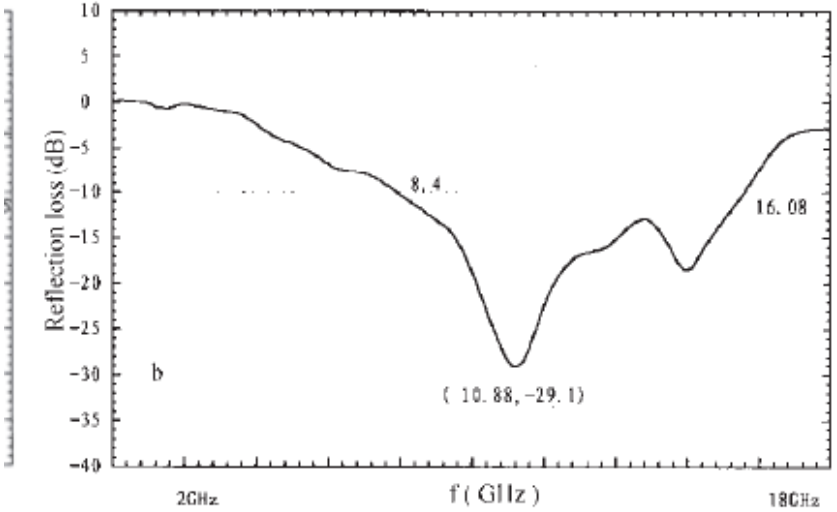
Microwave heating analysis

Heating and cooling kinetics

Critical parameter: Coating temperature must not exceed +80 °C, will degrade otherwise

CNT show strong MW absorption between 2-20 GHz
2,45 GHz ”open” frequency
Less radar-disturbing turbines

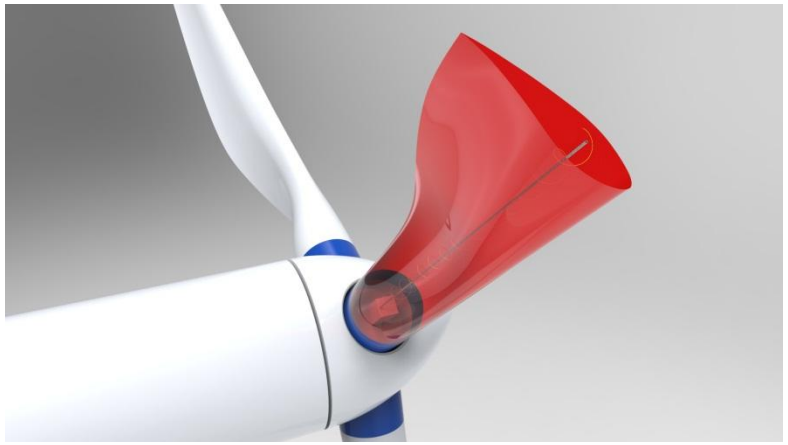


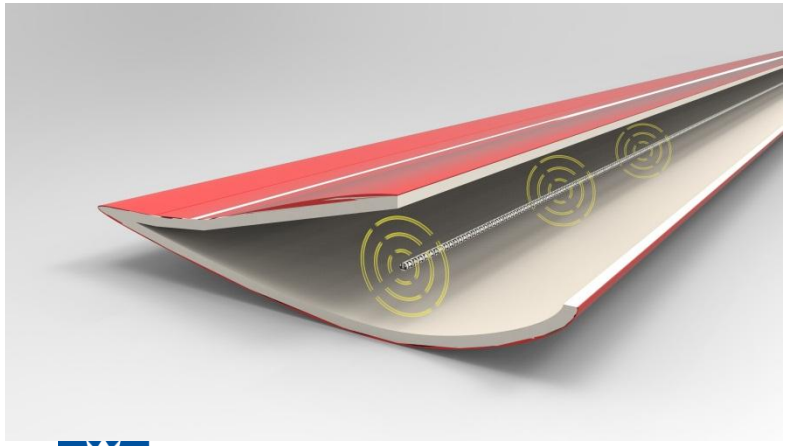


Microwave Absorption Characteristics of Carbon Nanotubes

Xiao-Gang Sun, Ming Gao, Cheng Li and Yiqiang Wu
Nanchang University, Sun nanotech Co Ltd
China

Introduction to Microwave De-Icing





Technology

- Carbon Nanoparticles in a coating or film absorb MW radiation and generate heat
- Microwaves generated and transmitted to each wing through a waveguide

New installation or Retro-fit

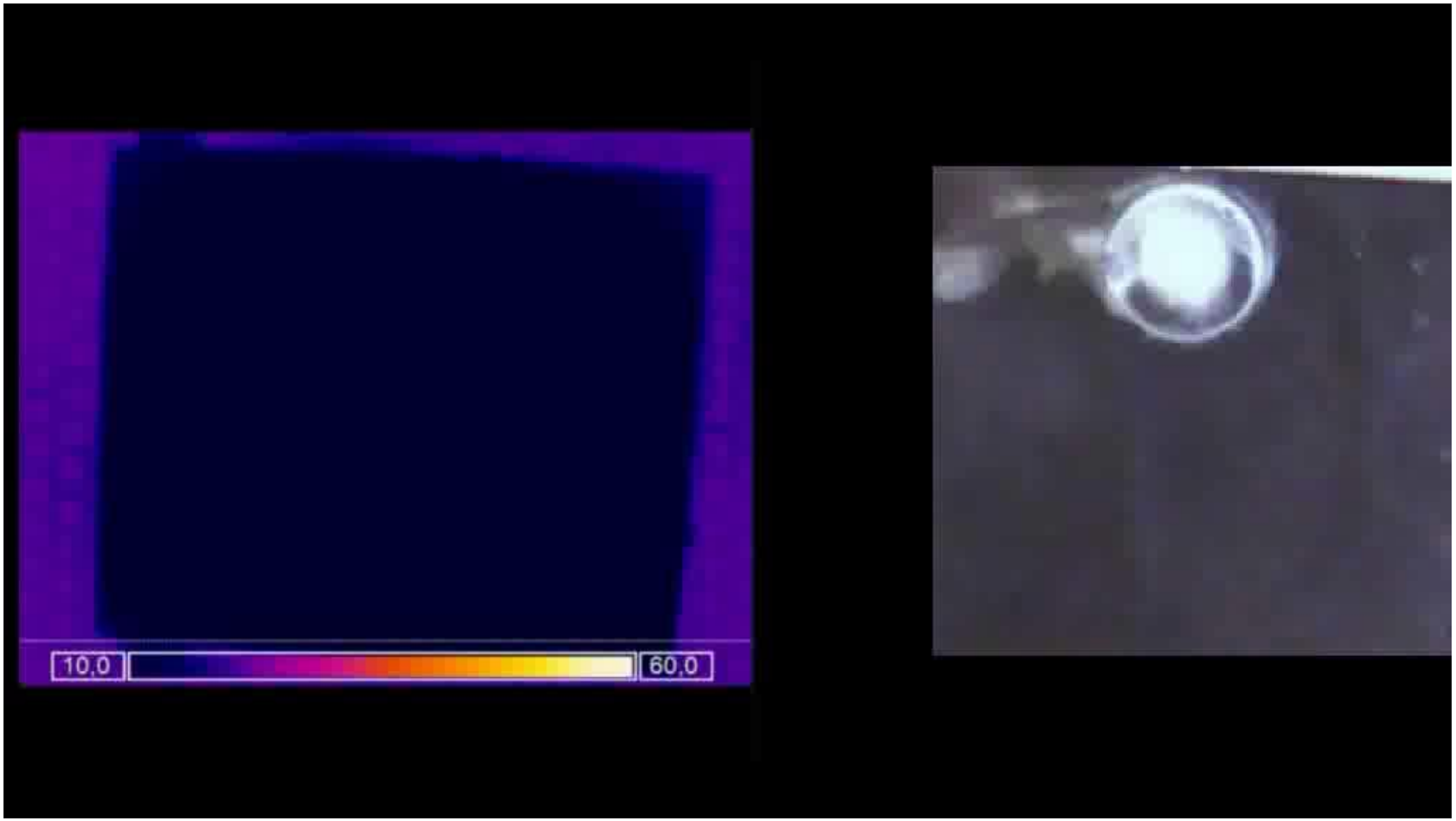
- MW generator and waveguide inside every wing
- Anti-icing whilst in operation

Status

- Prototype operating in lab
- Proof of concept at Vattenfall test site during the winter of 2014/2015

Microwave heating of a small sample (PU coating with CNT)

Infrared camera **web camera**



Micro-DeIce –
Active De-icing of Wind Turbines with Advanced Surface Coatings

Main funding from the Swedish Energy Agency

Partners:

- **SP** (coordinator, lab scale development work, testing, etc.)
- **Re-Turn AS** (developer of technology, microwave absorbent supplier)
- **MW Innovation AB** (consultant with long experience from de-icing activities)
- **Pegil Innovations AB** (supplier of MW sources, incl. waveguides)
- **Vattenfall R & D AB** (potential end user of the technology**)**

Project duration: **2 years**

Project budget: **3.9 MSEK**

Project start: **September 1, 2013**

SP Technical Research Institute of Sweden

Swedish Energy Agency

Micro-DeIce –
Active De-icing of Wind Turbines with Advanced Surface Coatings

Project objectives

To develop a combination of microwave absorbent and top-coating with good durability and deicing properties with low energy consumption

Project Content

- Optimization of composition of CNT-containing PUR and/or Epoxy-based gelcoats with respect to MW absorption and heat generation. Combination of active and passive coatings.
- Evaluation of ageing properties of the coatings. Repeated exposures and characterization of mechanical and surface properties
- Development of gelcoat formulations optimized for spray coating
- Scale-up trials
- Design and construction of microwave sources, incl. wave guides for field tests
- Security and health, incl. lightning sensitivity analyses
- Field tests

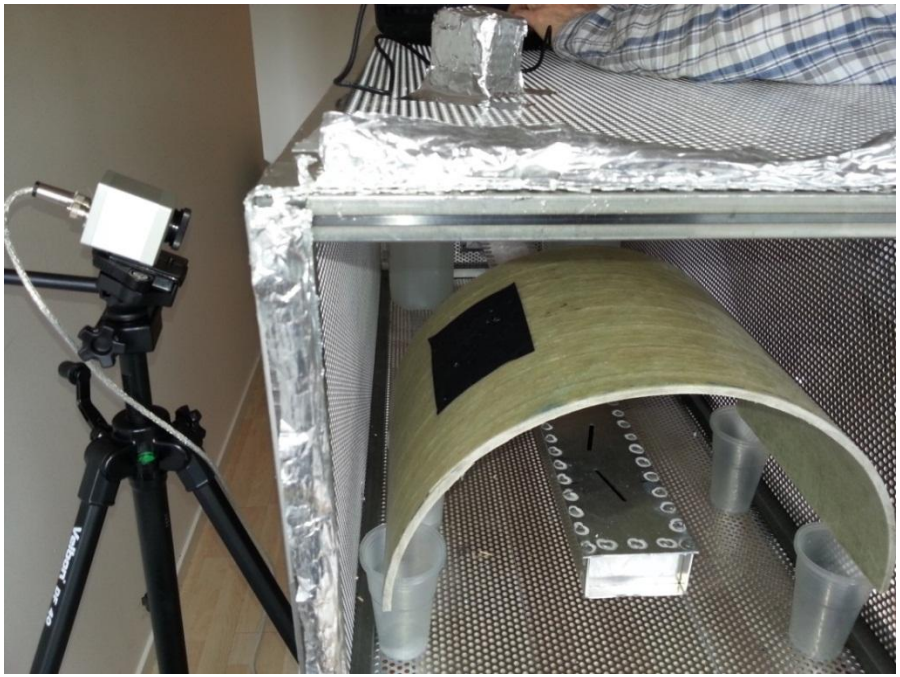
TopNANO initiative, passive de-icing

- One of 4 Nordic Top Level Research Initiatives (Nordic Innovation), started 2011
- Budget ca. 3 M€
- Participants from academia and industry:
  Research partners: SP and KTH (SE), Aarhus University (DK) and VTT (FI)
  Industrial partners: SAAB Aerospace, Vattenfall, Electrolux, Nibe, Danfoss, SAPA (Gränges) , MW Innovation, Re-Turn, n-Tec
  Coordinator: SP Chemistry, Materials and Surfaces (former YKI, Institute for Surface Chemistry)
- *Targets: to* develop heavy-duty coatings with no or significantly reduced ice adhesion in three important industrial sectors: windpower, aircraft and heat exchangers

www.topnano.se

Laboratory trials - Microwave de-icing - Equipment

Laboratory set-up with Faraday cage, IR/optical cameras, different waveguides, different foils and coatings



Modified kitchen microwave oven

Evaluation of ageing properties of Microwave-absorbing coatings

Repeated exposures and characterization of mechanical and surface properties

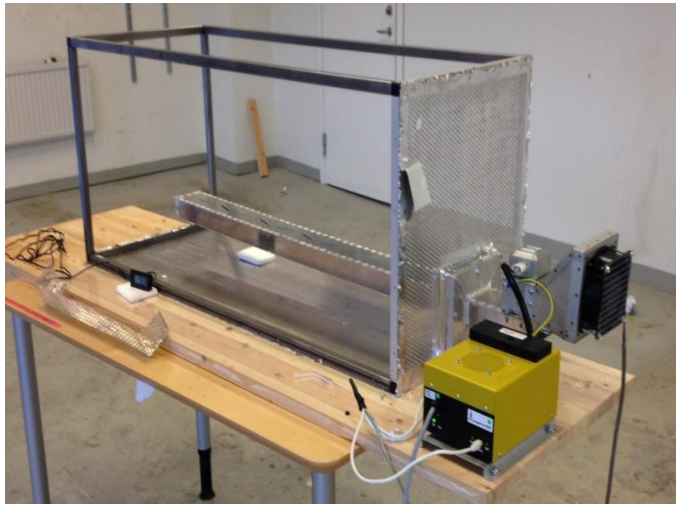
Modified kitchen microwave oven

”Laser Gun”:
Temperature control is important.
Must not exceed 80 °C

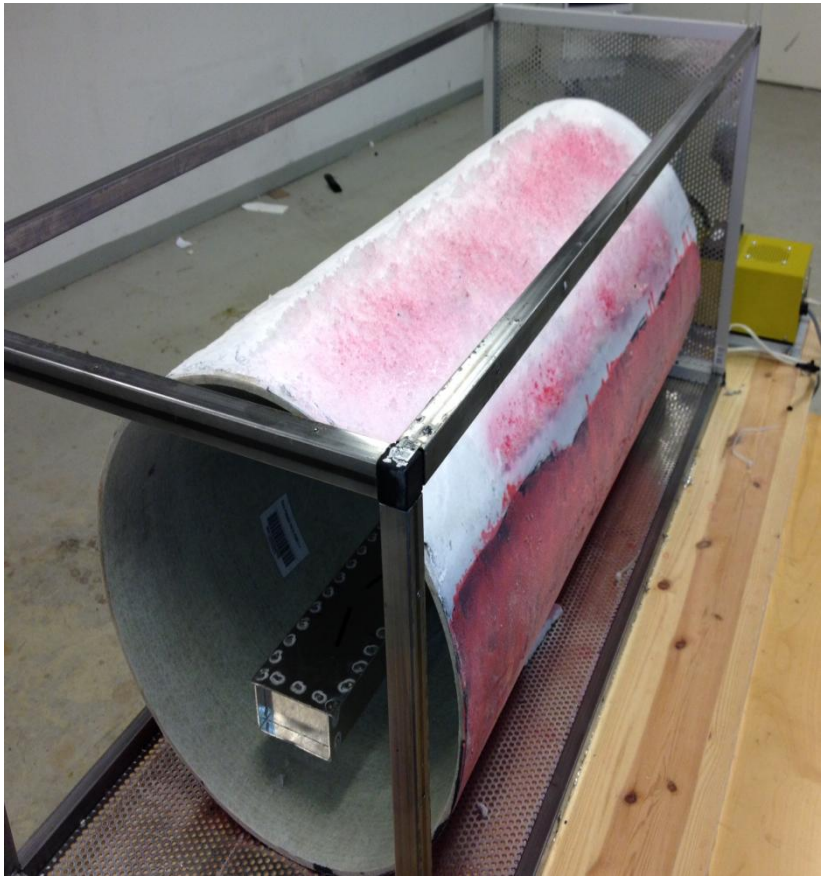
Why modify the MW oven?

- Uneven exposure at short treatment times
  (wave length at 2.45 GHz = 12 cm)
- Too slow sample rotation

Microwave de-icing - Scale up trials



polyester/GF pipe



Microwave de-icing - Scale up trials

substrate: polyester/GF pipe (from -20 °C freezer)
active layer: PU coating with CNT
topcoat: white PU coating with ice spray + snow (red-coloured)

waveguide

Microwaves irradiate 50 cm of pipe, blue arrow

Micro-Delce

Microwave de-icing - Scale up trials

Print screens from Web camera film

start

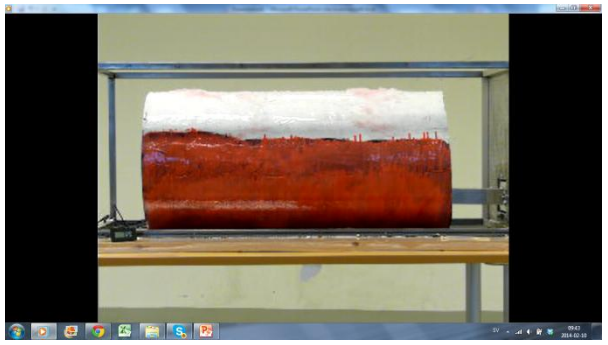
4 minutes

8 minutes

12 minutes

14 minutes

15 minutes



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Micro-Delce

Microwave de-icing - Scale up trials

Print screens from Web camera film

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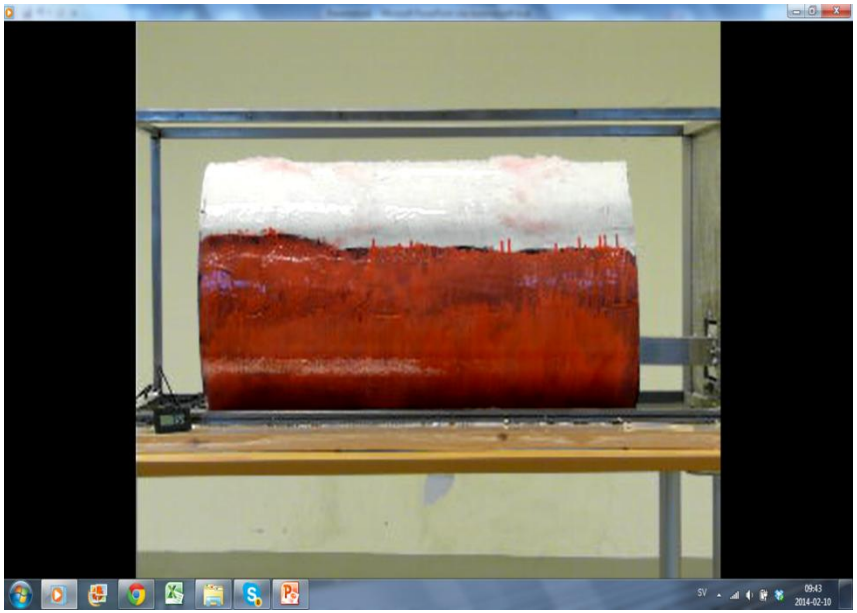
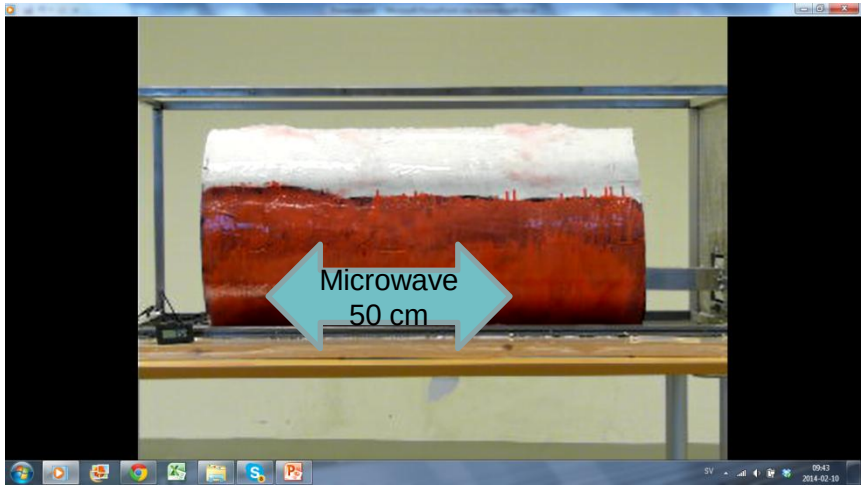
15 minutes



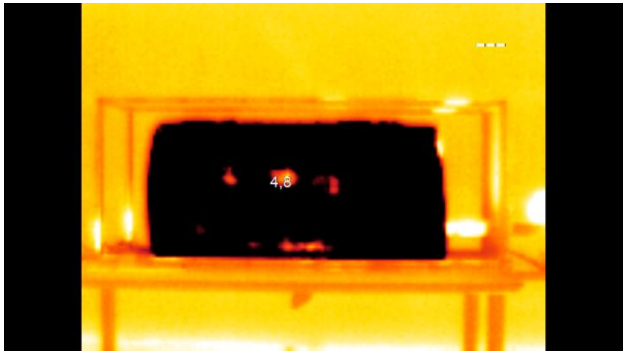
Microwave de-icing - Scale up trials



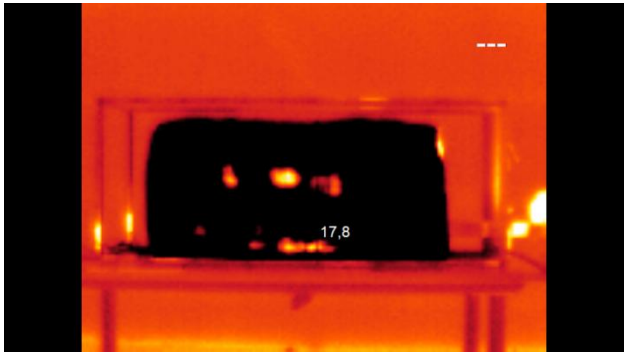
Microwave de-icing - Scale up trials

Print screens from IR camera film

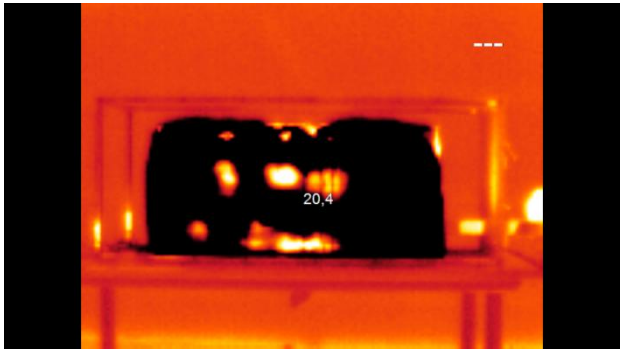
4 minutes



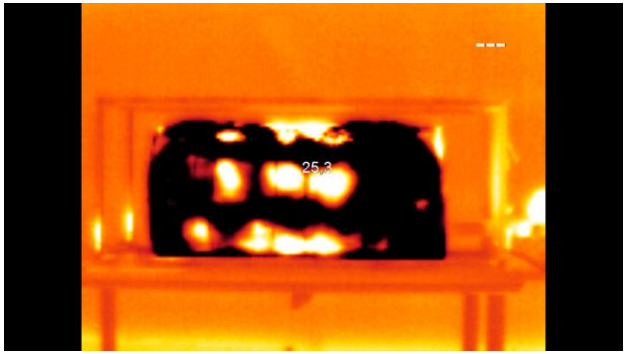
6 minutes



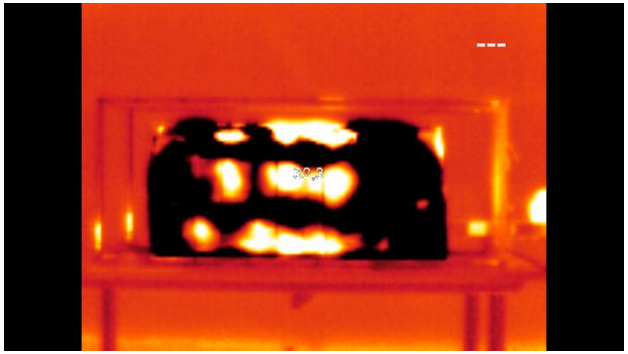
8 minutes



10 minutes



12 minutes



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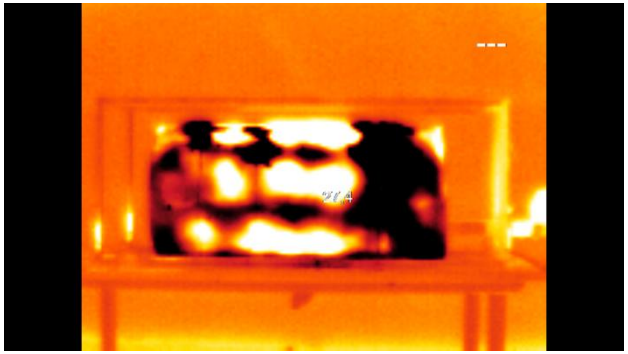


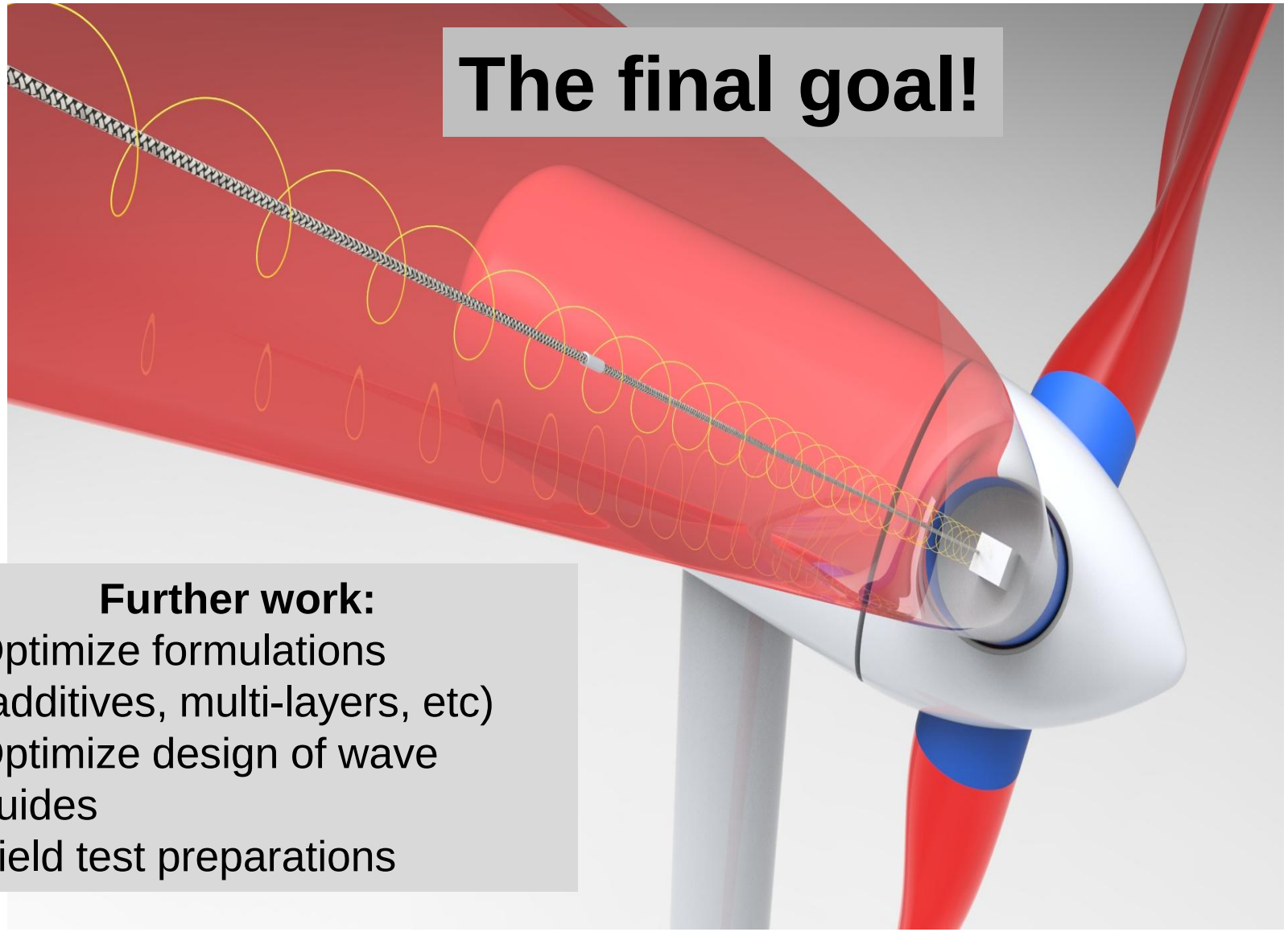
Note: No radiation or heating on the right side!

Comparison of Anti-Icing Solutions

Estimates for Hot Air and Foils!

	Hot Air	Heating Foils	Microwave
Energy use	Relatively high	Low	Low
Anti-Icing method	Ice Removal	Ice Prevention	Ice Prevention and Ice Removal
Installation Price / MW	Relatively low	Relatively high	Relatively low
Lightning Problems	No	Yes (probably expensive repair)	No (but needs confirmation)
Damage Resistant	Yes	Probably most sensitive	Yes

The final goal!



Further work:

- Optimize formulations (additives, multi-layers, etc)
- Optimize design of wave guides
- Field test preparations

Summary

- Microwave heatable coatings for anti-icing or de-icing demonstrated, Laboratory tests promising
- Enabling expansion of wind power to cold climate
- Energy savings versus competing solutions
- Cost savings versus competing solutions (capital, variable costs)
- Extra benefit: reduced radar interference
- Next phase: further upscaling in field tests, sponsored Swedish Energy Agency

Acknowledgements

- All co-workers and co-authors
- The Swedish Energy Agency for financial support

Thank you for your attention!

Questions? kenth.johansson@sp.se

Come and see us at **Booth 39** in the Exhibition Hall here at Winterwind!