

# Developments in Standardization: Test Methods for Anti-Icing Properties of Rotor Blade Coatings

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- 2 AMETEK Atlas Material Testing Technology
- 3 DIN-Standards Committee NAB
- 4 Fraunhofer Institute for Manufacturing Technology and Advanced Technology IFAM
- 5 RENOLIT SE

Winterwind 2024, 20.03.2024

## Motivation



Anti-Icing properties- requirement for standardized measurement

- wind turbines
- power transmission lines
- transportation such as aviation, ships, cars, railways
- Refrigerators and heat exchangers
- Photovoltaic devices

*Glaze  
Rime and Hoar frost  
Hail  
Snow*

## **Outline:**

### „Developments in Standardization: Test Methods for Anti-Icing Properties of Rotor Blade Coatings“

#### **ISO- Technical Committee**

#### **Background of Ice-Adhesion**

- Principles of anti-icing strategies
- Methods to determine anti-icing properties
- Conditions and constraints of measurements

#### **Adhesion Tests - conditions and parameters**

- Measurement setup's
- Normative parameters – variation range

#### **Current State of technical specifications**

# ISO/TC 35/SC 9/WG 32 "Coating materials for wind-turbine rotor blades"



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## ISO/TC 35/SC 9 - General test methods for paints and varnishes

### ISO/TC 35/SC 9/WG 32 - Coating materials for wind-turbine rotor blades

- Part 1: Minimum requirements and weathering
- Part 2: Determination and evaluation of resistance to rain erosion using rotating arm
- Part 3: Determination and evaluation of resistance to rain erosion using water jet
- Part 5: Measurement of transmittance properties of UV protective coatings
- Part 6: Determination and evaluation of ice adhesion using centrifuge

#### *Mirror committees:*

*NA 002 DIN-Normenausschuss Beschichtungsstoffe und Beschichtungen (NAB)*

- *NA 002-00-16 AA - Beschichtungen an Rotorblättern für Windenergieanlagen*

The world map shall visually demonstrate the geographic distribution of the committee members, not the acceptance by ISO  
source: <https://www.iso.org/committee/47996.html?view=participation>



Developments in Standardization:  
Test Methods for Anti-Icing Properties of Rotor Blade Coatings  
Speaker: Ute Bergmann  
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## „Determination and Evaluation of Ice Adhesion“

- Simple setup,
- Very low cost,
- Evaluation of physical parameters,
- Highly controllable and repeatable method,
- Defined Ice volume
- Reality of experiment

## „Determination and Evaluation of Ice Adhesion“

### ISO TS 19392-6:2023

Determination and evaluation of ice adhesion using centrifuge  
Status: published

### ISO/PWI TS 19392-9:2023

Determination and evaluation of ice adhesion using horizontal shear test  
Status: work item



# Setup and influence of measurement paramters



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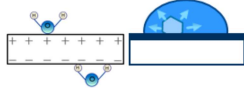
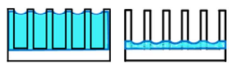
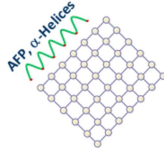
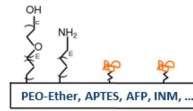
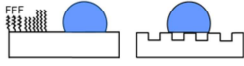
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## How to prevent the accumulation of ice on a surface? Passive Strategies



- Hydrophobic and ultrahydrophobic surfaces

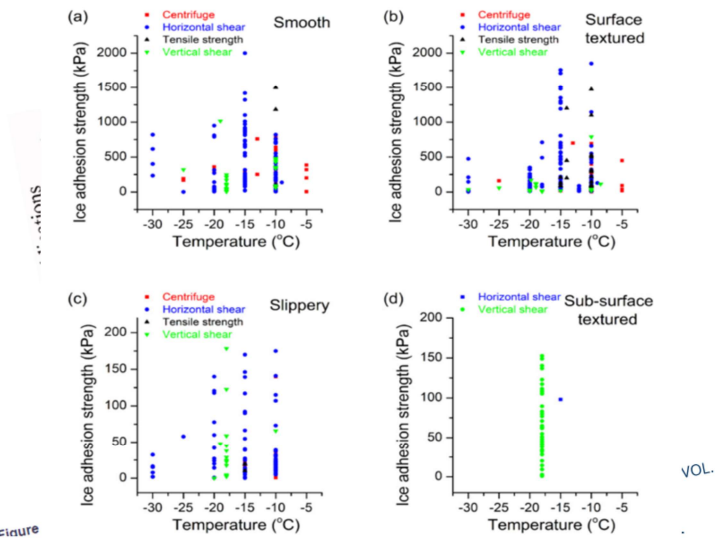
- Hydrophilic-hydrophobic clustering

- Retarding the crystal growth

- Active Switching of Surface properties:

- Roughness
- Interfacial energy

## Comparison of results of different test arrangements

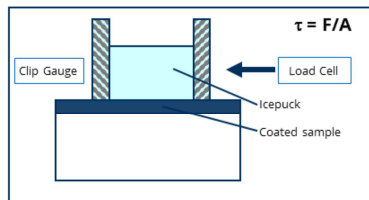


**Fig.:** Ice adhesion strength plotted against temperature ~ by using different ice adhesion test methods

Source: Zhiwei He, "Design of Icephobic Surfaces by Lowering Ice Adhesion, Strength: A Mini Review" Coatings 2021

## Methods to determine Anti-icing properties

### Horizontal Shear Test (Pusher Test)



**Load:** Quasistatic shear rate

**Ice type:** static

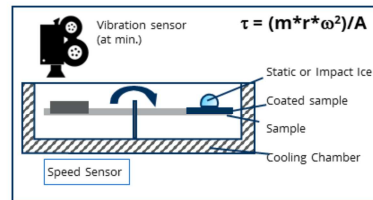
**Iced area:**

**Test temp.:**

**Statistic:** 5 - 10

**Interface vis. Exam.:** x

### Centrifugal Test



**Load:** Rotational speed,

**Ice type:** Acceleration

static, impact

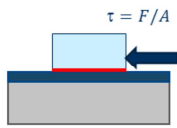
x

-1 – -20°C

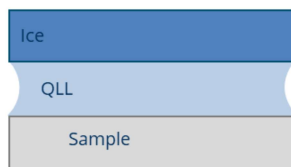
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## The Quasi Liquid Layer -

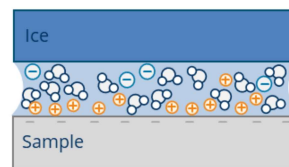
Liquid-like layer, liquid interface layer, lubricating interface layer, premelting layer, ...



- A thin layer of water molecules whose properties are more similar to those of the liquid than the solid phase of water
- Can lead to very low adhesion forces
- The thickness and viscosity of the QLL decreases with temperature
- If the thickness of the QLL becomes smaller than the roughness, occurs interlocking → higher adhesion



Quasi Liquid Layer (QLL)



Electrochem. Double Layer (EDL)

## Determination of the ice adhesion by centrifugal test

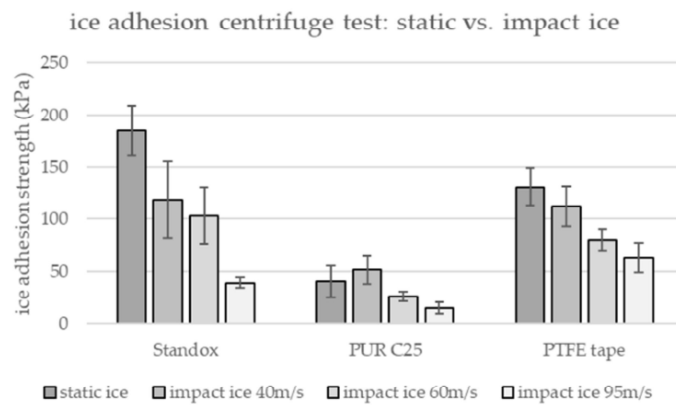
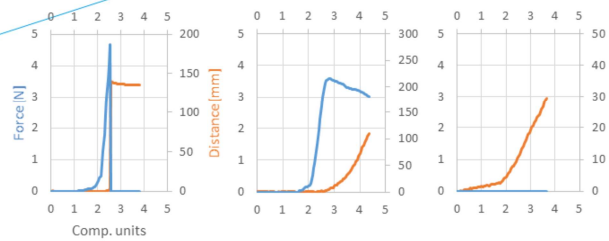
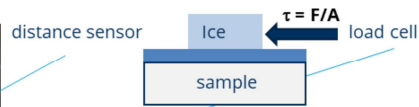
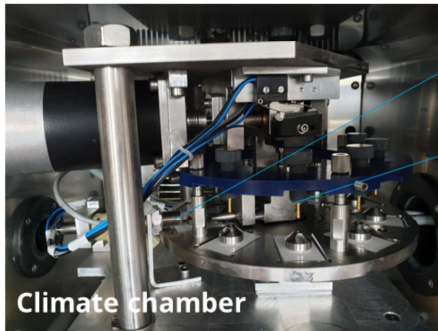


Fig.: Comparison of the Ice Adhesion test results for different ice types

Source: Nadine Rehfeld et al.; *Parameter Study for the Ice Adhesion Centrifuge Test*, *Appl. Scs.* 2022, 12, 1583, [doi.org/10.3390/app12031583](https://doi.org/10.3390/app12031583)

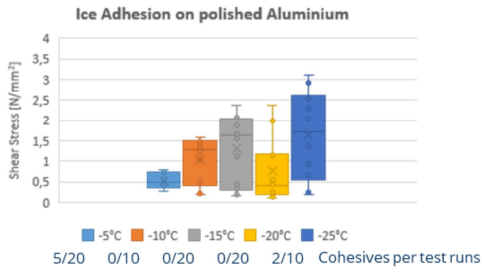
## Determination of the ice adhesion forces by horizontal pusher test



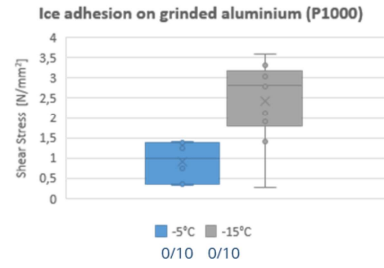
Ice adhesion strength is mainly affected by:

- the temperature,
- surface roughness and porosity,
- surface energy,
- ice type (entrapped air bubbles that act as local crack initiators)

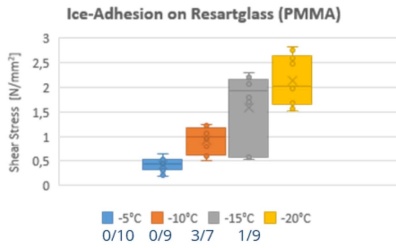
# Effect of temperature and roughness on ice adhesion



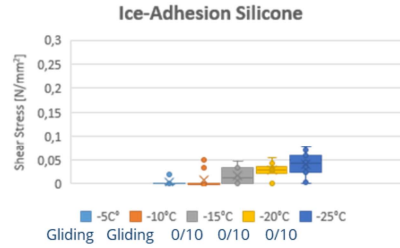
Ice adhesion of deionized water on polished aluminium at different temperatures



Ice adhesion of deionized water on grinded aluminium at different temperatures



Ice adhesion of deionized water on PMMA at different temperatures

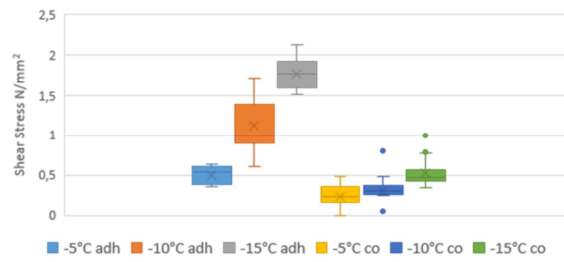
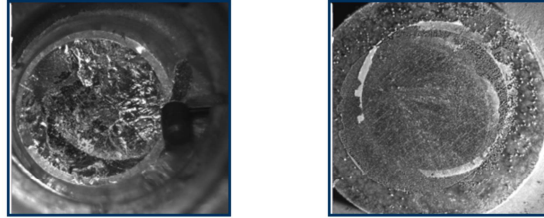


Ice adhesion of deionized water on silicone at different temperatures

Source: S. Apelt, U. Bergmann; *Insights into the interface during ice adhesion; Nanoexpress measurements 5 (2024) 015001, doi.org/10.1088*

## Effect of crack path on ice adhesion

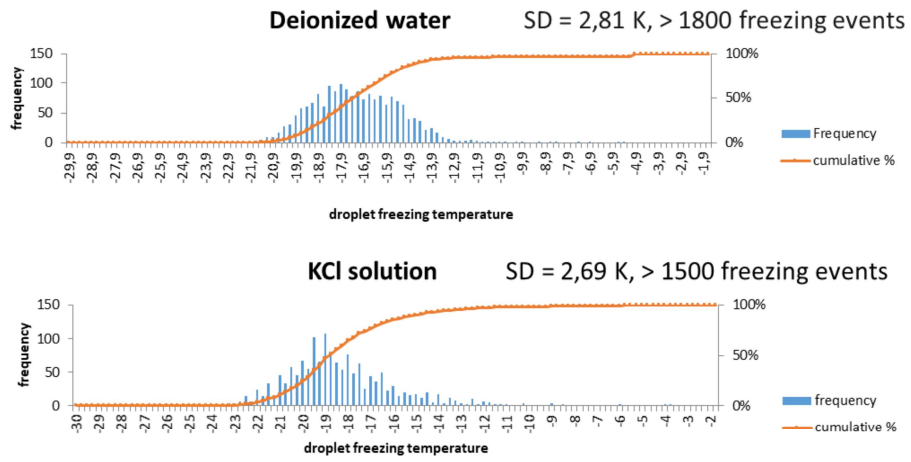
Cohesive versus adhesive fracture:



Cohesives per test run: 15/20 23/30 29/42



## Frequency of heterogeneous nucleation



Source: Sabine Apelt; *Herstellung und Charakterisierung pyroelektrischer P(VDF-TrFE)-Beschichtungen für Anti-Eis-Anwendungen*, Ph.D. TU Dresden, 2020

# Summary, conclusion and questions



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## Summary and conclusion

Test Standards for Ice-adhesion:

- 😊 Standardization of ice adhesion measurement is essential!
- 😊 TS for centrifugal test ✓
- 😊 TS for shear test - work item
- 😊 Definitions: Ice-type
- 😊 Cooling rate
- 😊 Test temperature
- 😊 Acceleration/ Load rate
- 😊 Control of fracture interface
- 😊 Statistics
- 😊 Definition of a well suited reference material

**EISABnet**  
Netzwerk eisabweisende Oberflächen

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Thank you for your attention.

GEFÖRDERT VOM



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