Topical Symposia
Room Town & Country B - Session TS1-FrM
Anti- and De-Icing Surface Engineering

Moderators: Kevin Golovin, University of Toronto, Canada, **Jolanta-Ewa Klemberg-Sapieha**, École Polytechnique de Montréal, Canada

8:00am **TS1-FrM-1 Penguin-Inspired Anti-Icing Surfaces***, **Anne Kietzig (anne.kietzig@mcgill.ca)**, M. Wood,* McGill University, Canada **INVITED**

Over the past decades considerable research efforts have been made to provide novel and ideally passive anti-icing strategies. Broadly these efforts have either started off from aiming at reducing the amount of water present for solidification on a given surface or at facilitating the dislodging of already grown ice. In our work, we have addressed both aspects by taking inspiration from the South American penguin *Spheniscus humboldti* which exhibits strategies to not only shed water but also already accreted ice. The biomimicry of the Penguin feather's functionality is achieved by using a compliant finely woven wire cloth to mimic the microstructure of the feather in combination with using laser-micromachining to further decorate the latter with nanogrooves. Laser-micromachining in combination with selective post-processing techniques further allowed us to render the surface chemistry of our biomimetic surface either hydrophilic or hydrophobic, which allowed us to selectively identify the role of surface chemistry on our anti-icing surface. Our results from this biomimetic surface not only highlight that different physical mechanisms are at play when considering water and ice shedding, but also emphasizes the role of the hierarchical surface structure. Laser-machined nanogrooves with hydrophobic surface chemistry clearly support water shedding. Whereas, the porosity and compliance of the microstructure favors a multitude of evenly spaced crack initiation locations with facile and short pathways for crack propagation, which accordingly leads to exceptionally low ice adhesion strengths. In conclusion, our biomimetic approach highlights that having learnt from a natural example and abstracting the relevant features and functionalities to engineering provided us with a framework that exploits fracture mechanics to design the ice-shedding property and wetting science to separately design the water-shedding property.

8:40am **TS1-FrM-3 Screening of Anti-Icing Strategies Against Aeronautic Secondary Icing***, **Paloma García (garciagp@inta.es)**, J. Mora, F. Carreño, M. González, A. Agüero Bruna,* Instituto Nacional de Técnica Aeroespacial (INTA), Spain

Ice protection is an important issue in the aeronautic field, which has been traditionally faced by the use of active systems (systems that need energy support). In last decades, the use of several passive solutions, based on surface engineering strategies, has been explored to replace the active systems, or to decrease their energy consumption. However, so far the idea of completely avoiding ice accretion with a passive system seems utopic. In addition, ice accretion affects different sections of aircrafts, but to present, a single method efficient in all possible icing locations, has not been found. Thus different solutions must be designed for each specific application, and testing should be undertaken attending to the different location issues.

For instance, electrothermal active systems are widely used to protect sensible areas on aircrafts, i. e. leading edges. Those systems increase the surface temperature to avoid ice accretion or release or melt the ice once it has been accreted. As a result, icing in the downstream area of the wing's chord is caused by exposure to this ice-melted water droplets as well as to direct supercooled water. This is considered as secondary or runback icing resulting in an important challenge in aviation, and the use of anti-icing solutions can perhaps contribute to avoid or reduce this issue.

In this work, 12 materials and references, attending to 5 different anti-icing strategies have been tested using a common methodology. These include Slippery Liquid Infused Porous Surfaces (SLIPS), elastomer coatings, superhydrophobic surfaces and low surface energy materials. The test methodology includes the evaluation of ice adhesion after impact icing in an icing wind tunnel (IWT) as well as ice accretion through direct impinging of supercooled droplets and after melting or heating in an active system in the IWT.

Among the studied materials, several coatings showed ice accretion reduction and some of them also significantly reduced ice adhesion. In general, 2 strategies showed more promising results in terms of anti-icing features: SLIPS and elastomeric coatings. In addition, low roughness, low surface energy and high water droplet mobility (low contact angle hysteresis) were correlated with anti-icing behaviour. These are easy to measure properties which do not require complex equipment that can be considered as indicators of potentially good anti icing and de-icing performance. Results also showed that superhydrophobic solutions reduced runback icing as a result of a reduced interaction of the melted ice droplets with the surface.

9:00am **TS1-FrM-4 Influence of Organosilicon Based Modification on Ice Adhesion and Wettability of Unsaturated Polyester Gelcoats Surfaces***, **Rafal Kozera (rafal.kozera@pw.edu.pl)**, B. Przybyszewski, K. Zolynska,* Warsaw University of Technology, Materials Science and Engineering, Poland*; B. Sztorch, R. Przekop,* Adam Mickiewicz University of Poznan, Poland*; A. Boczkowska,* Warsaw University of Technology, Materials Science and Engineering, Poland

In recent years, the world of science and industry has paid a lot of attention to coatings as a functional materials.Used as the outer layer on an composite elements, they fulfill a number of extremely important functions.Starting with protection against weather conditions, through improving mechanical properties, and ending with decorative functions. One of the significant problem in many industries is accumulation and build-up of ice and snow what is a negative and unwanted phenomenon. Ice formation and accretion present serious, sometimes catastrophic, safety issues for all kinds of industry where application of the composites components has already become common e.g. wind turbines blades, aircrafts, electric and telecommunication infrastructure as well as other composite constructions exposed to supercooled water droplets both on the ground and in the air. In example, ice on wind turbine blades or aircrafts disrupts airflow by altering the shape of the wing surface, which leads to increased drag and decreased efficiency of the systems what cause necessity for more often servicing and utilization of energy consuming systems.

In the present work, composite materials based on unsaturated polyester resin and authors' chemical modifications were prepared and characterized in order to find compromise between hydrophobic and icephobic properties. Studies were conducted by means of goniometer to investigate contact angle, hysteresis and roll of angle, ice adhesion tester in order to find correlation between modified surface and ice and profilometer for roughness characterization.

Presented work is conducted in the frame of the project entitled"ICEphobic SURfaces for components based on polymER composites- IceSurfer" (no. LIDER/16/0068/L-9/17/NCBR/2018) under the LIDER program of the National Center for Research and Development, Poland.

9:20am **TS1-FrM-5 Quasicrystalline Coatings Exhibit Durable Low Interfacial Toughness with Ice***, **Kevin Golovin (kevin.golovin@utoronto.ca)**,* University of Toronto, Canada

Ice accretion can adversely impact many engineering structures in commercial and residential sectors. Although there are many reports of low-ice-adhesion-strength materials, a scalable and durable deicing solution remains elusive, as ice detachment is dominated by interfacial toughness for large interfaces. In this work, two durable quasicrystalline coatings (QC1 and QC2) were applied on aluminum substrates using HVOF thermal spray. XRD confirmed the quasicrystalline phases. Except for the roughest QC2 sample (root-mean-squared roughness ≈ 7 µm), a toughness-mediated regime of fracture was observed when detaching longer lengths of ice from the quasicrystalline coatings. The interfacial toughness was calculated to be 0.9 J/m^2 for the smoothest QC1 sample (root-mean-squared roughness ≈ 1.5 µm) and 1.1 J/m^2 for the smoothest QC2 sample (root-mean-squared roughness ≈ 0.3 µm), demonstrating that low-interfacial toughness coatings are possible to fabricate from metallic materials. Apparent shear strengths as low as 30 and 80 kPa at an ice length of 20 cm were observed for QC1 and QC2, respectively. A small imposed deflection could also dislodge 20 cm-long pieces of accreted ice adhesively. Interfacial toughness increased with surface roughness in line with the concept of a shielding factor that hinders crack propagation. Finally, the mechanical durability of the smoothest QC1 and QC2 samples was confirmed using abrasion, UV irradiation, pencil scratching, elevated temperature, and chemical contamination. Overall, thin quasicrystalline coatings exhibit the unique combination of low interfacial toughness and high durability, leading to long-lasting ice protection applicable to many different surfaces.

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