

## The Exploration of Icephobic Materials and Their Future Prospects in Aircraft Icing Applications

Omid Gohardani\*

Ever since the early days of aviation, scientists have undertaken numerous challenges pertaining to the influence of atmospheric conditions on flight characteristics and performance. A specific flight scenario may expose the airframe of the aircraft to various factors related to weather conditions such as lightning strikes, gust, rain, hail, snow and in rare conditions volcanic ash [1]. Although it is unlikely that an aircraft will be subjected to all of these conditions simultaneously, the sudden temperature change that the vehicle experiences between on-ground conditions and the cruise altitude can be considerably significant. The aforementioned conditions hence place stringent requirements on the external surfaces of the aircraft and their respective material characteristics.

A paramount factor of interest which remains highly frequent occurs upon impingement and accretion of super-cooled liquid droplets on the various aircraft surfaces and consequent aircraft icing, as shown in figure 1. Liquid water content, droplet size, surface characteristics and temperature, further define the character of the formed ice on the aircraft [2]. In extreme cases these impacts may result in rain erosion on the aircraft fuselage [1]. Due to the adverse impact that icing can impose on the aircraft's flight characteristics, various measures are taken in order to minimize the effects of icing such as usage of thermal, mechanical and chemical ice protection systems. While regions where potential icing conditions may occur often have been avoided by pilots throughout the history of aviation, the increasing transport predictions of the future will ensue that icing conditions always cannot be avoided. Current civilian and military aircraft occasionally have to operate in icing conditions despite the existing safety concerns and still be able to complete their missions successfully. A recurring subject in this context is therefore whether or not icephobic external surface materials, which in essence will repel the ice and minimize ice adhesion, can be identified for usage on both commercial and military aircraft.

The quest for potential icephobic materials has been ongoing since the very first icing encounters during flight. In search for the ultimate icephobic material, researchers have utilized many different substances and compounds applied on the leading edge of an airfoil, such as various oils, grease, paraffin, glycerin, corn varnish, and commercial



Figure 1: Various super-cooled droplet sized encounters in presence of a rising air system and high humidity resulting in aircraft icing [3].

paint. This list is however not exhaustive and many other materials and coatings have been considered in order to reduce the ice adhesion during flight [3,4]. With the inception of nanotechnology, the spectra of potential materials that may fulfill the desired characteristics of low ice adhesion and hydrophobicity have expanded considerably. Inspiration from lotus-leaf like superhydrophobic surfaces has instigated further research on the role of superhydrophobicity on ice-repellence. Along this path, other materials that have generated the interest of many researchers are carbon nanotubes implemented in composite materials, given that the latter are rather commonly utilized materials in aeronautics. In particular one recent study conducted by Gohardani et al. [5], has considered rain erosion characteristics of a set of polymer matrix composites reinforced with carbon nanotubes, as external surface materials on aircraft, depicted in figure 2. As an extension to this study, Gohardani examined the ice adhesion characteristics of these materials in aircraft icing applications [2] and further explored their wettability properties [6,7].

Among numerous recently identified ice-repellant solutions, a nano-fluorocarbon [8], silicone coating [9] and slippery, liquid-infused porous surfaces (SLIPS) can be mentioned. In this context, the most promising solution SLIPS, provides a stable and ultrasmooth, low-hysteresis lubricant overlayer maintained by infusing a water-immiscible liquid into a nanostructured surface [10]. This approach



Figure 2: A possible impact scenario, with liquid impacts ensuing in either splashing, ice adhesion or erosion [5].

Received October 30, 2012; Accepted October 30, 2012; Published November 02, 2012

Citation: Gohardani O (2012) The Exploration of Icephobic Materials and Their Future Prospects in Aircraft Icing Applications. J Aeronaut Aerospace Eng 1:e116. doi:10.4172/2168-9792.1000e116

Copyright: © 2012 Gohardani O. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

enables a chemically functionalized solution which has an affinity to the infiltrated liquid and arrests its movement.

In light of the preceding discussion, a number of challenges have to be tackled for a successful implementation of an icephobic material in aerospace applications. These include, but are not limited to the following:

1. The icephobic material has to withstand erosion and wear and other weathering conditions in terms of its structural integrity.
2. The material has to be tested in a realistic and dynamic environment such as inside an icing tunnel at high enough velocities, analogous to the conditions encountered during flight or tested during actual flight tests.
3. The question of whether the icephobic material should be applied as a bulk material or a coating shall be addressed.
4. The icephobic material has to preserve its initial characteristics in terms of its hydrophobicity despite exposure to severe wear mechanisms such as erosion and corrosion.
5. The material has to be inexpensive to manufacture and coherent in terms of material properties and equally environmentally friendly.

On a broad perspective the aforementioned points, partially explain the challenge of fulfilling all the requirements for a successful implementation of an icephobic material in aerospace applications. One of the difficulties that often emerges in aircraft icing research stems from the intricate nature of replicating realistic flight conditions, prior to any flight testing. Such research hence requires a large icing tunnel, which essentially is represented by a refrigerated wind tunnel where either a model of the aircraft or its full sized components can be tested in realistic flight conditions.

With the advent of new technologies and novel categories of flying vehicles, such as Micro Air Vehicles (MAVs) and Unmanned Air Vehicles (UAVs) and their extended range operations, the issues associated with flight in icing conditions are often not incorporated during the initial design stage. Hence, an icephobic material fulfilling the aforementioned criteria would indeed extend the operational hours of these vehicles and contribute to safer flights in the future.

It can be stated that while modern meteorological systems such as the current icing potential (CIP) and forecast icing potential (FIP) are able to outline icing potentials with a detailed diagnosis provided for instance by the National Oceanic and Atmospheric Administration (NOAA), they are unable to foresee every single occurrence of icing that a flying aircraft may encounter. As all commercial airliners utilize ice protection systems, any improvement of the existing systems will result in economical savings and contribute to further growth of the aviation industry in the long term. In addition, such solutions would further be beneficial for general aviation aircraft which often lack the same ice protection systems as commercial airliners. A consecutive effect of savings as a result of a successful implementation of an icephobic material, will further pave the path for a higher safety at a lower cost, in conformity with the demand of increasing passenger transport, predicted for the future.

Conclusively, open access journals such as the Journal of Aeronautics & Aerospace Engineering published by the OMICS Publishing group, enable that the boundaries of information retrieval and sharing between scientists are removed and further research can be undertaken in different scientific fields. The purpose of this editorial has thus been to incline perspective researchers and scientists within

the aircraft icing and advanced materials communities and aerospace engineering professionals to disseminate their research findings to a larger extent in open access journals. This approach facilitates access to the latest research findings for the scientific community and the general public, without any information barriers.

## References

1. Gohardani O (2011) Impact of erosion testing aspects on current and future flight conditions. *Prog Aerosp Sci* 47: 280-303.
2. Gohardani O (2011) The influence of erosion and wear on the accretion and adhesion of ice for nano reinforced composites used in aeronautics.
3. Gohardani O (2009) The influence of erosion and wear on the accretion and adhesion of ice of polymeric composites loaded with nano particles - First Year Progress Report. Technical report, Cranfield University.
4. Leary WM (2002) We Freeze to Please: A History of NASA's Icing Research Tunnel and the Quest for Flight Safety. NASA/SP-2002-4226.
5. Gohardani O, Williamson DM, Hammond DW (2012) Multiple liquid impacts on polymeric matrix composites reinforced with carbon nanotubes. *Wear* 294: 336-346.
6. Gohardani O, Hammond DW (2012) Droplet interaction and dynamic wettability of advanced materials used in aeronautics. In: Tahman M, Brebbia CA (2012) *Advances in Fluid Mechanics IX*, WIT Press, UK.
7. Gohardani O, Hammond DW (2013) Dynamic and static wettability of advanced materials used in aeronautical applications. *International Journal of Computational Methods and Experimental Measurements* (In press).
8. Wang H, He G, Tian Q (2012) Effects of nano-fluorocarbon coating on icing. *Appl Surf Sci* 258: 7219-7224.
9. Richards WD, Chuck TL, Farrell SD (2012) Ice release systems comprising silicone and grease compositions. European Patent Application.
10. Kim P, Wong T-S, Alvarenga J, Kreder MJ, Adorno-Martinez WE, et al. (2012) Liquid-Infused Nanostructured Surfaces with Extreme Anti-Ice and Anti-Frost Performance. *ACS Nano* 6: 6569-6577.