A civilian-operated Mil Mi-8 utility helicopter lands at a Forward Operating Base in Afghanistan. As in arid and dusty conditions, flying operations in freezing conditions present their own occupational hazards in this rugged country.

Bad Vibrations

Researchers are studying a variety of ways to eliminate icing on helicopters.

BY THOMAS WITHINGTON

Ice is an enemy of all aviators, including helicopter pilots. The unique flight attributes of these aircraft place them in high demand for difficult civilian operations such as emergency medical services, remote and off-shore transportation and search and rescue. Due to the on-call nature of many of these operations, they cannot always wait for perfect visual meteorological conditions with mild temperatures. The danger that a helicopter crew may unwittingly encounter freezing temperatures and icing when performing such missions cannot be discounted. Hot air and heated blades are technologies available in some aircraft, while ultrasonic technology has the potential to provide protection in the future.

Canada's Department of National Defence encountered some nasty surprises in a 2007 experiment involving an AgustaWestland CH-149 Cormorant helicopter belonging to the Canadian Forces Air Command and a Sikorsky CH-53 heavy-lift military helicopter equipped with a spray rig designed to form a cloud of freezing water around the Cormorant. Ice accumulated on the Cormorant's main rotor blades until the centrifugal force of their movement eventually shook the ice free, sending it crashing into the aircraft's tail rotor. This caused the tail rotor to dislodge ice that had accumulated there, and the aircraft began to suffer severe vibrations. Such aircraft behavior would be alarming in the best of times, but would be particularly unwelcome for a crew dashing through clouds of snow on a dark night en route to a medical pickup on a remote oil rig.

Aircraft icing is caused by super-cooled water that remains a liquid at temperatures below 32 degrees F (0 degrees C) but is denied a surface upon which to freeze. An aircraft flying through a cloud of super-cooled water thus provides the surface, and ice builds up — accretion. This can be especially dangerous, as it can alter the aerodynamic characteristics of the rotor blade airfoils and aircraft fuselage, causing excessive vibration, increased weight and drag, and other hazards.

As ice begins to accumulate on the leading edges of the rotor blades, the deformation of the airfoils and the corresponding need for increased torque to maintain any given flight situation are accompanied by airframe vibration as the blades become more unbalanced. This vibration can have adverse effects on the helicopter's airframe, increasing structure stresses and, at the least, raising discomfort levels inside the aircraft, which can accelerate crew fatigue.

Ice also affects the aerodynamic performance of the rotor blades. The larger the ice buildup, the more pronounced the drag of the rotor blades. As a result, more power is required from the engine and transmission, a process that, if left unchecked, eventually

U.S. Department of Defense

Canadian Department of Defence

Canada's location and climate mean that helicopters are at real risk from icing. The Canadian Air Command's Sikorsky CH-149 Cormorant helicopters have been involved in icing trials to ascertain the dangers that ice can pose to helicopter operations.

requires full power to maintain altitude. If accretion continues unchecked, the aircraft begins to descend. If the pilot is lucky, warmer air will be present at lower altitudes and the ice will melt. However, an absence of warmer air beneath the helicopter will prevent the ice from melting and may cause an uncommanded altitude loss.

Moreover, helicopter pilots must contend with the many different forms icing can take, each having different effects. For example, water droplet size affects the position, texture and size of the ice buildup. Larger droplets, for example, hit a rotating blade and run back toward the trailing edge before becoming a solid, increasing the surface area covered by the super-cooled water and therefore increasing the size of the ice buildup.

The flight trials of the Cormorant illustrated how dangerous ice can be. This frozen water can become a deadly missile when it is shed by the rotor blades. Not only does it risk damaging the tail rotor and the airframe itself, but it may also hit exterior protrusions on the aircraft, such as antennas and night vision systems. Such damage can be expensive, and these systems may also be relied on by the crew to enhance flight safety and to assist in the completion of the mission.

While helicopter pilots and operators have several measures that can mitigate the dangers of icing, there is not yet a silver bullet that can eliminate all incidences of icing on a helicopter at no cost in weight or power consumption.

Invented by BF Goodrich in the 1920s, the pneumatic boot is still in use on rotary and fixed-wing aircraft today. The boot is an inflatable rubber structure that fits on the leading edges of helicopters' vertical and horizontal tail surfaces and is inflated to break off ice as it accumulates. However, such a system cannot remove ice from an aircraft's rotor blades, and there remains a threat of shedding ice moving around the airframe.

Another method to reduce ice buildup on a helicopter is fluid-based, preflight deicing, spraying aircraft with a heated glycol-water mix to remove any ice that has built up prior to flight. Using such a product is better and safer than doing nothing, but it is not designed to keep the aircraft ice-free once in flight. Furthermore, glycol-based products are not considered environmentally friendly. There are other issues beyond the cost of such procedures, including the risk that such a product may damage to the helicopter's lubricants and the composite components that are increasingly finding their way into helicopter construction to reduce weight and improve strength and resistance to corrosion.

These materials may not react well to the sudden change in temperature when ice is removed by heated glycol-based products, and delamination is possible. Published in 2004, a paper[1] written by three scientists engaged in helicopter icing research at the U.S. Army Cold Regions Research and Engineering Laboratory in New Hampshire and the U.S. Army Research Laboratory in Adelphia, Maryland, warns that "the thermally induced stress caused by rapid thermal gain, and differential heating of dry and ice-covered surfaces, have the potential for invisibly weakening multi-layered aircraft structures of composite materials."

They note that "non-visible damage such as delaminations, disbonds and structural integrity losses can occur due to low temperature exposure and freeze-thaw cycling effects." Preflight deicing has a secondary disadvantage in that it can be time-consuming and an aircraft may have to wait for deicing equipment to become available before the procedure can be performed. This can be a problem for helicopters that are called upon at short notice to perform emergency missions.

Another helicopter anti-icing option is to use warm air bled from the aircraft's engines through pipe work embedded in tail surfaces, for instance. The disadvantage here is that the air becomes colder as it moves away from the heat source, with a risk that deicing coverage is not uniform; areas near the heat source are ice-free while those farther away remain ice-covered.

Heating mats are another alternative. These mats use an embedded mesh of electrical wire through which a current can pass to heat the surface and prevent the formation of ice. These heating mats can be installed on rotor blades or around engine inlets to prevent ice formation and ingestion into the turboshaft powerplants. Yet, as with the other systems, heating mats add a weight penalty and drain system power.

Along with heating mats, helicopters can also use electro-thermal heating systems in their rotor blades. These raise the blades' temperature to remove ice, or to stop the ice from forming in the first place. However, as all ice protection systems bring costs as well as benefits, such equipment may add an additional burden to the helicopter's electrical system.

Goodrich Corp. provides the ice protection system, consisting of heating mats on the rotor blades and a deicing system on the windshield, on AgustaWestland's AW-139. Although this equipment brings a weight penalty, such systems are the only means by which a helicopter can be certified to fly in icing conditions. The company told *AeroSafety World,* "Ten years ago, these were considered niche systems, but now we are seeing a number of customers requesting this kit." In addition to customers in North America and Europe, operators in Central Asia, especially those involved in the oil and gas industries, are showing interest in the AW-139's ice protection system. Despite the arid terrain of this part of the world, it can suffer harsh winters: "At the moment, the requests for ice protection systems are mainly for aircraft servicing oil platforms and performing search and rescue, but we are also seeing a number of VIP customers requesting this equipment so that they can fly their helicopters to the ski slopes, for instance." In order to save fuel and weight costs, elements of the AW-139's ice protection system can be removed during warmer months when such protection is not needed.

Curtiss-Wright produces the electronics for the Rotorcraft Ice Protection System (RIPS). The rationale behind RIPS is to prevent the buildup of ice on the rotor blades, thus

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A Eurocopter EC-145 engaged in search-and-rescue operations on a snow-covered mountain. The very nature of helicopter search-and-rescue operations means that these aircraft may often be at risk from encountering icing conditions.

preventing the problem of ice being thrown around the airframe as it detaches. John Kuperhand, president of Curtiss-Wright Controls Integrated Sensing, Avionics and Electronics, notes that the latest versions of RIPS, installed on the Sikorsky S-92 and soon appearing on the S-76D, are exceptional in that the equipment is "fully automatic," and does not require the pilot to turn RIPS on and off during the flight. Kuperhand says that RIPS is "the first system that was certified for full flight operation into known icing conditions by the U.S. Federal Aviation Administration, the European Aviation Safety Agency and Transport Canada." The automatic nature of the system is achieved via the use of "software to determine the proper application of where, when and how frequently heat has to be applied to rotor blades to prevent the buildup of ice."

RIPS uses heating elements embedded inside the helicopters' rotor blades. These elements are cycled through a pre-determined timing sequence to prevent ice accretion. The advantage of this approach is that it does not melt the ice through a sudden transmission of heat. Because of the dynamics of the movement of a rotor blade, "if you pump a lot of heat and suddenly melt the ice, you'll melt the ice on the front end and it will re-ice and add to ice formed on the back end," notes Kuperhand: "Our system acts by breaking the [adhesion] between the ice and the blade, and lets the ice peel off the front to the back." When the ice is shed from the leading portion of the airfoil in a gentle, controlled manner, it reduces the danger of larger ice chunks impacting the fuselage, tail rotor and other components.

RIPS has been in production for five years and is offered as an option on Sikorsky's S-92 and S-76D helicopters because some companies operate them in warmer climates, where ice protection is not a major concern. Curtiss-Wright concedes that RIPS adds weight, but Kuperhand says that the company is "looking at size and total weight reduction" to make the product less intrusive on the helicopter's performance. The reliability and availability of the system have won operator approval.

Curtiss-Wright also provides electronic controllers for windscreen and engine inlet ice protection. Windshield ice protection is provided by heating elements embedded inside the transparencies. This approach is slightly less sophisticated than RIPS, given that "the pilot can see if ice is forming, and just turn on the windshield de-icer, or it can be set for automatic operation triggered by temperature," says Kuperhand. The important consideration for rotor blade deicing is that, given the blades' speed and location, a pilot cannot see whether ice is forming and must therefore rely on a system like RIPS which can sense the temperature changes and then take appropriate deicing action.

Other research is intended to develop the next generation of products to help safeguard rotary operations in freezing temperatures, and one promising option could be the use of sound. A 2006 research report[2] said, "Ultrasonic modes generated by horizontal shear waves produce sufficient interface stresses between a host structure and ice to remove the accreted ice layer."

What this means is that ultrasound could dislodge ice by disrupting the adhesion between the ice and the blade. Ice is prevented from forming, and ice that formed before the activation of the system can be removed through the use of sound vibrations. An example of such technology can be found in many household bathrooms: Electric toothbrush technology uses ultrasound to shift plaque from teeth using a similar disruptive technique. The researchers discovered that within five minutes, a layer of ice 0.06 in (1.5 mm) thick could be melted using this technique and that "as the amplitude of the ultrasonic waves increased, the ice adhesion strength decreased."

Ultrasound is still some years away from becoming a viable ice protection system for helicopters. Furthermore, given that such a system would use electrical power and require dedicated equipment to generate the ultrasonic waves, the power generation and weight penalties associated with the system remain undefined. However, as with many aspects of aviation safety equipment, trade-offs and balances have to be reached. Ice protection systems may be an additional drain on electrical and engine power, but the protection that they offer can mean the difference between safe flight and hazardous operations.

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Notes

1. Dutta, Piyush K.; Ryerson, Charles C; Pergantis, Charles.*Thermal* "Deicing of Polymer Composite Helicopter Blades." 2004.
2. Palacios, Jose L.; Smith. Edward C., Pennsylvania State University, "Ultrasonic Shear Wave Anti-Icing System for Helicopter Rotor Blades." 2006.