FLIGHT SAFETY FOUNDATION
HELICOPTER SAFETY
Vol. 16 No. 6 For Everyone Concerned with the Safety of Flight November/December 1990

Inflight Icing and the Helicopter

Results of a U.S. Army investigation into the unique hazards facing rotary wing operations in the winter environment offers timely tips for all helicopter flight crews.

Traditionally, helicopter operating manuals have addressed the issue of inflight icing and its effect on helicopter performance with a caution or a warning to the pilot to avoid an icing environment. Such restrictions and limitations were acceptable when helicopters were viewed as aircraft operating primarily in visual meteorological conditions (VMC). Since early helicopters lacked the equipment and sophisticated systems normally employed for flight in instrument meteorological conditions (IMC), there was little justification for expending valuable time and resources on helicopter icing research and development.

However, modern helicopters have a greatly expanded concept of operations and today they routinely perform a broad range of tasks in IMC and marginal VMC. It is this expansion of the helicopter's operating envelope that compels a more thorough understanding of the hazards associated with inflight icing.

Hazards of Inflight Icing

The risks associated with flight in subzero precipitation or moisture have been known since the pioneering days of fixed-wing flight. Typically, we have characterized icing problems by their effect on lift, drag, weight and thrust. It is readily accepted that inflight icing reduces thrust and lift, and increases drag and weight, all to the detriment of aircraft performance.

Rotary-wing aircraft also suffer from these effects when exposed to icing conditions and, in addition, are susceptible to various complications that are not common to fixed-wing aircraft. Although many questions remain regarding helicopter icing and its impact on aircraft performance and mission effectiveness, researchers are uncovering significant insights into this facet of helicopter development.

Rotor Ice vs. Wing Ice

The rotor blade icing process and its subsequent effect on helicopter performance cannot be analyzed in the straightforward manner used to explain ice accretion on the leading edges of a fixed-wing aircraft. Spanwise elements of a rotor blade, unlike the leading edges of an airplane's wing, move through the air at various airspeeds.

Rotor blade icing is made even more complex by the constantly changing angle of attack experienced by the helicopter's main rotor blades in normal forward flight. These obvious and unique characteristics of the helicopter's lifting system, combined with differing surface temperatures along the blades' spanwise sections and smaller airfoil thicknesses, make helicopter rotor blade icing complex and extremely hazardous.

Autorotational Qualities Degrade

A major operational hazard is the deterioration of normal autorotational qualities. The adverse effect of main rotor icing on autorotational performance was documented during artificial and natural icing tests conducted by the U.S. Army. A major finding was that moderate ice accumulation (approximately one-half inch) on inboard portions of the Bell UH-1H Huey rotor blade (and those on similar type aircraft) was sufficient to seriously deteriorate autorotational qualities by causing a loss of 22 rpm during autorotation at 70 knots indicated airspeed (KIAS). Deterioration of normal autorotational rpm results from ice accumulation in greater amounts near the inner portions of the rotor disc which directly affects blade efficiency with respect to upward airflows during autorotation.

The reported result is that with about one-half inch of ice on the inner portion of the main rotor blades, minimum (safe) rotor rpm cannot be maintained during autorotation.

Helicopter pilots cannot judge or estimate main rotor blade ice accumulation by observed buildup on the windshield or other parts of the aircraft, because icing occurs at an accelerated rate on the rotor blade as compared to accumulation on the fuselage. A more reliable method for monitoring the buildup of rotor blade ice on UH-1 type aircraft is to compare power requirements after the formation of inflight ice to power settings prior to ice detection.

Researchers indicate that blade icing of one-half inch or greater on the UH-1 will be accompanied by a five- to six-pound per square inch (psi) torque increase over the no-ice power requirement. Icing tests conducted in the United Kingdom document cases where significant autorotational rpm deterioration occurred with only six percent power increase over the no-ice power requirement.

Helicopter pilots should remember that even small buildups of ice on the main rotor blades can significantly deteriorate the available autorotational rpm to a level where safe landings cannot be assured. When inflight icing occurs, most of the damage to autorotational performance is done by the initial ice accumulation, i.e., the first one-quarter inch of ice on the rotor blade. For helicopter pilots, this means that every encounter with icing should trigger an expanded crosscheck with careful attention to power settings.

If continuous increases in power are required to maintain altitude and airspeed, there is reason to suspect that autorotational rpm has been compromised and the aircraft should be removed quickly from the icing environment.

If the accumulation of rotor blade icing deteriorates autorotational rpm, then it would seem that the shedding of rotor blade ice would be welcomed. Inflight shedding of rotor ice can and does occur. Unfortunately, it is as likely to create a problem as it is to relieve one.

Symmetrical (affecting all rotor blades simultaneously in the same way) shedding of ice in flight can be beneficial by restoring the rotor blades to a more efficient or clean configuration, and by reducing the weight of the aircraft. Asymmetrical shedding (affecting fewer than all of the main rotor blades), however, can create extremely severe vibrations depending on the amount of ice discharged, the type of rotor system, and other factors. The severity of these vibrations has been documented by test pilots engaged in conducting natural icing studies with helicopters. Their reports identify numerous occasions where inflight icing tests have been aborted because of main rotor blade icing and subsequent asymmetrical shedding which caused vibrations so severe that it became all but impossible to read the instrument panel.

The severity of vibrations resulting from asymmetrically shedding rotor ice is generally thought to be a function of the unbalanced weight of the rotor system and therefore may be expected to be greater for two-bladed and three-bladed systems than those rotor systems employing four or more blades.

Frozen FOD

Ice shedding from the main or tail rotor can also produce problems apart from an unbalanced rotor system. Although documentation is less than authoritative, researchers have expressed a concern for structural or foreign object damage to the helicopter's fuselage, rotors or engines resulting from rotor blade shedding. This particular hazard appears to be more threatening to large multi-engine aircraft (more than 12,500 pounds) and especially for tandem rotor systems.

Asymmetrical shedding of rotor blade ice can be minimized by avoiding static temperatures lower than -5° C (23° F). Research tests with UH-1 type aircraft suggest that by rapidly varying main rotor speed or entering autorotation, symmetrical shedding may be induced when static temperatures are -5° C or warmer. Collective and cyclic inputs were generally ineffective in producing symmetrical shedding and may result in asymmetrical shedding. At temperatures below -5° C, it is generally not possible for a pilot to induce shedding.

The disastrous effects of inflight icing on helicopter engines have been reported in many publications. Inflight icing presents a hazard to normal engine performance in two major ways — ice ingestion and air starvation. Ice ingestion is minimized on many helicopters by the availability of engine anti-icing systems used to prevent to accumulation of ice deposits in the area immediately forward of the compressor section. When operating normally and environmental conditions do not overtax their capabilities, these systems considerably reduce the potential for damage from ice ingestion.

Even when aircraft are equipped with engine anti-icing systems, there remains a need for caution to ensure normal operation of the engines. Engine anti-icing systems will prevent the buildup of ingestible ice deposits only when outside meteorological conditions or aircraft operating conditions (most notably forward airspeed) do not exceed system design capabilities. As an example, when operating normally, the engine air inlet anti-icing system on the Sikorsky HH-3 (S-61) helicopter will maintain the engine inlet surfaces at or above 37.8° C (100°F). However, if outside air temperatures are very cold, extremely heavy icing conditions prevail, or the helicopter is maintaining a high forward airspeed, the engine air inlet anti-icing system will not be capable of maintaining a high enough temperature to prevent the buildup of ice in the engine inlet duct, and the potential for subsequent ingestion of ice deposits will exist.

Many HH-3 pilots have experienced occasions where cruise speeds in excess of 100 KIAS could not be maintained without illuminating the engine inlet anti-ice caution lights — an indication that the temperature of inlet air surfaces is not being maintained above 37.8° C and that the potential for ice ingestion has increased significantly. A common remedy for such conditions is to reduce airspeed to about 70 KIAS which gives the anti-ice system a chance to recover from the high airspeed or harsh outside conditions.

Skip the Ice Cubes, Please

Even when the engine air inlet anti-icing system is capable of sufficiently heating the engine inlet surfaces, there is still the threat of random ice ingestion if deposits on rotors, fuselage sections, antennas or windshield surfaces shed ice and it is directed into the engine air intake stream. Shedding ice deposits from the helicopter, often larger than household ice cubes, can be devastating to engine compressor blades.

Perhaps the most insidious aspect of engine anti-icing is the case where an engine anti-icing system has been activated and failed to perform as expected. When a failure or malfunction in the anti-icing system does occur and there is no accompanying cockpit annunciator light or instrument to alert the pilot of a failure in the anti-icing system, it may create a false sense of security and no warning that an engine failure may be imminent.

Air starvation of the engine due to accumulation of ice on the engine inlet screens has been reported by the U.S. Navy and by other operators. Several helicopters had engine flameouts due to ice accretion on the engine inlet screens, and, in one case, air starvation of both engines occurred only a few minutes after ice was first noticed forming on the aircraft. Flight in icing conditions with inlet screens installed is extremely dangerous and must be avoided if at all possible.

Using Archaic Criteria

Icing forecasts may be of little use to helicopter pilots if they are not informed about how the various forecast icing rates were first determined. The standard weather service methodology and terminology used to characterize and classify the icing environment was developed from inflight icing tests conducted on Douglas DC-4 and DC-6 type aircraft. Thus, such labels as trace icing, light icing, moderate icing and heavy icing, which are used to relate the rate of ice accretion on a fixed cylindrical probe on a DC-6, are of little use to the helicopter pilot in ascertaining or predicting the rate of ice accretion on a complex rotor system.

As an example, light icing is defined as an accumulation of one-half inch of ice on a small probe after 40 miles of flight. The rate of accretion is sufficient to create a hazard if flight is prolonged in these conditions, but insufficient to require diversionary action.

Although the prior definition may well be appropriate for a 100,000-pound airplane, there is no assurance that the rotating surfaces of a helicopter will accumulate only one-half inch of ice over the same 40 miles. Further, while one-half inch of ice on the wing of a large airplane might appropriately be called "light icing," there is every reason to believe that one-half inch of ice on the leading edge of most helicopter rotor systems could result in tragic consequences if autorotation became necessary. ♦

[*This article is reprinted from the U.S. Army publication* Flightfax *in the interest of sharing safety information with the worldwide aviation community. — Ed.*]

They're Not All Heliports

We once used only one term to describe a place where helicopters landed. Now the lexicon has expanded, with these terms listed in the U.S. Federal Aviation Administration (FAA) Advisory Circular 150/5390-2.

Heliport. A heliport is an identifiable area on land, water, or structure, including any building or facilities thereon, used or intended to be used for the landing and takeoff of helicopters. The term heliport as used in this advisory circular, in Federal Aviation Regulation (FAR) Part 77, Objects Affecting Navigable Airspace, and in FAR Part 157, Notice of Construction, Alteration, Activation, and Deactivation of Airports, applies to all sites, including helistops, used or intended to be used for the landing and takeoff of helicopters.

Helistop. A helistop is an area used or intended to be used for the landing and takeoff of helicopters engaged in dropping-off or picking-up passengers or cargo.

Public Use Heliport. A public use heliport is available for the takeoff or landing of helicopters without prior authorization being required to use the facility.

Private Use Heliport. A private use heliport is a facility for exclusive use by the owner or other persons having prior authorization to use the facility.

Hospital Heliport. A hospital heliport is a public use or private use heliport supporting helicopter air ambulance services.

Final Approach and Takeoff Area (FATO). A defined area over which the final phase of the approach maneuver to hover or landing is completed and from which the takeoff maneuver is commenced.

Takeoff and Landing Area. The takeoff and landing area is a cleared area containing a FATO.

Helipad. The helipad is a surface used for parking helicopters. It may be located inside or outside of the FATO or the takeoff and landing area.

Helideck. The helideck is an elevated surface used for parking helicopters. It may be located inside or outside of the FATO or the takeoff and landing area. ♦

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