JOURNAL OF AIRCRAFT
Vol. 35, No. 6, November–December 1998

Certification and Operation of Helicopters in Icing Environments

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This paper presents the issues gathered from a survey carried out on helicopter airframe and engine manufacturers, and helicopter operators and aircrews, throughout Europe and Canada. The work focused on in-flight icing and the problems of manufacturing, testing, and subsequently, operating helicopters in such conditions. Most commercially operated helicopters are not permitted to fly in known icing conditions, because they are not certified to do so by the aviation authority. However, during the survey it was established that owing to commercial pressures, aircrews do fly in icing conditions, using helicopters that do not have an icing clearance. In addition, there is a disparity between what the airframe manufacturers and icing specialist know are the most dangerous icing conditions, and the knowledge held by helicopter aircrews. Aircrews would like a better method of ice detection and would prefer an ice predictor, which indicates that an icing environment is approaching, rather than a detector, which tells them that they are already in icing. Furthermore, operators would like all helicopters to have a full icing clearance if there were no operational penalties. In conclusion, the industry as a whole would like to verify that the icing envelope described in the certification regulations is applicable for helicopters. The current parameters have been modified from fixed-wing aircraft, which tend to cruise at much higher altitudes and in colder, drier conditions.

Introduction

THIS paper describes work carried out as part of a European Commission-funded project entitled European research on aircraft ice certification (EURICE). The project involved aerospace manufacturers, research establishments, and universities from six European countries. The project was composed of three work packages.

Work package 1: aircraft icing incidents database design and implementation.

Work package 2: new atmospheric icing data acquisition.

Work package 3: current regulation analysis.

This paper reports on the activities carried out by Loughborough University in work package 3 (WP3). Further information about EURICE and work packages 1 and 2 is available in Amendola et al.[1]

WP3

The primary activity of WP3 was to carry out a critical review and analysis of current certification and operational regulations, for turboprop aircraft and helicopters in icing conditions. The purpose of this was as follows.

1) To identify any areas where improvements to the current certification or operational procedures would improve aircraft operations or aviation safety.

2) To evaluate, where possible, the impact of any proposals.

The improvements are defined as any change that would result in an increase in the capability of turboprop aircraft and helicopters to operate safely in an icing environment. This paper discusses some of the results from WP3 relating to helicopters, whereas the results for turboprop aircraft are reviewed in Render and Simpson.[2]

Problem Definition

The principle reasons why helicopters have problems with operating in icing conditions are as follows.

1) Helicopters are particularly susceptible to icing, owing to the main rotor being the method of generating lift, maneuverability, and forward movement.

2) The majority of commercially operated helicopters are not certified to fly in known icing conditions. However, the increased commercial use of helicopters in a wide range of weather conditions, for example, in the off-shore oil industry, means that there is growing interest among operators in acquiring helicopters with at least some form of icing clearance.

3) Helicopters are particularly susceptible to icing, because they fly at cruise altitudes of between 1000 and 10,000 ft. These altitudes often contain moisture in the form of supercooled water droplets. When these droplets come into contact with the aircraft, ice is likely to form.

4) Helicopters have limited available power. Manufacturers and operators would prefer to use this for moving the aircraft, rather than for powering ice-protection systems.

Approach

It was decided that the most effective method of investigating the certification and operation of helicopters for icing conditions was to carry out survey interviews with those organizations that design, certify, or operate helicopters. The organizations interviewed were two helicopter manufacturers, two engine manufacturers, and six helicopter operators. One major European helicopter manufacturer declined to be interviewed. Interviews took place in Canada and Europe. All of the organizations interviewed were selected because they had a large commitment to helicopters and had direct experience with icing conditions. In addition, meetings were held with four national certification authorities. These meetings did not form part of the survey, but were used to gain background information.

The interviews were carried out in a structured manner, using a detailed questionnaire. Such an approach allowed an in

Presented as Paper 98-0075 at the AIAA 35th Aerospace Sciences Meeting, Reno, NV, Jan. 6–9, 1998; received March 11, 1998; revision received Aug. 18, 1998; accepted for publication Aug. 19, 1998.

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depth enquiry, while enabling the interviewer to control and guide the interview. By having a detailed questionnaire, it was possible to maintain the consistency of presentation and information gathering over the period of interviews. The questionnaire was also used as a place to record interviewee responses. In addition, whenever possible, interviews were recorded using a portable cassette tape recorder. Separate parts of the questionnaire were produced for the operators, aircrews, ground crews, and manufacturers.

Results

When discussing the results, it must be remembered that these represent the depth of knowledge and opinions of only those individuals interviewed. The results should not be regarded as the complete level of icing expertise within the helicopter industry. However, given the fact that much of the information was corroborated by many individuals and organizations involved in the survey, the information can be taken as a good indication of the current level and type of icing knowledge. Some of the issues raised, particularly by the operators and aircrews, are different from the views of the icing experts. Such differences illustrate the need for icing knowledge to be effectively communicated throughout the helicopter industry. (An example of this can be seen in the section titled Most Severe Conditions.)

A summary of the information gathered from the surveys is reported here. A more detailed report, which includes information gained from similar activity carried out with turboprop manufacturers and operators, can be found by examining Ref. 3. The results are divided into three sections: a review of the different levels of icing clearance, manufacturers' issues, and operators' issues.

Icing Clearance Certification Levels

There are three levels of clearance given to helicopters and their operators

Zero Clearance

Zero clearance covers the majority of commercial helicopters operating under the JAR-29 airworthiness regulations.[4] Operators must not deliberately encounter or route helicopters into areas of known in-flight icing. Furthermore, if a helicopter inadvertently encounters icing, it must immediately leave the area. The majority of commercially operated helicopters have zero clearance.

Limited Icing Clearance

Limited icing clearance is described by the United Kingdom's (UK) Civil Aviation Authority (CAA)[5] as, "a prescribed envelope in which the rotorcraft may be safely operated in icing conditions, either for continuous periods or for a sufficient time to allow safe exit from the conditions, should this prove necessary." Limited icing clearances are only given by the CAA to specific operators, to conduct agreed operations with particular aircraft. There are significant differences between flying in icing conditions over the sea and over land. Over the sea there is, on nearly all occasions, a positive temperature layer from 0 to 500 ft altitude. This provides a zone where, if a helicopter needs to avoid icing conditions, it can guarantee to do so. Over land, there is often no positive temperature layer near the ground, and this layer may be colder than at altitude. However, over the sea, owing to the positive temperature layer, helicopters usually have an escape route from these conditions. It is this escape route that allows the UK to grant limited icing clearances. Helicopters with limited icing clearances must have ice-protection systems on the engines intakes, pitot tubes, and cockpit windows. They must also have some reliable means of measuring ice-accretion rates. This is to ensure that the conditions do not become too severe without the aircrew being aware of them. To obtain the clearance certification, the aircraft must be flown in natural icing conditions to the same level of severity at which clearance is requested. This *real* evidence will be combined with evidence gained from test rigs and simulations. A description of the type of test evidence that must be produced from natural icing trials may be found in Refs. 5 and 6.

Full Icing Clearance

This level of icing clearance certification allows helicopters to be flown in conditions described in Appendix C of JAR-29.[4] This document defines the atmospheric envelope in which helicopters must be able to operate to receive a full icing clearance. The icing envelope is identical to the one used for certifying fixed wing aircraft.[7] To gain a full clearance, helicopters will have full ice protection on the main and tail rotors, the engine intakes, and possibly the stabilizer.

Manufacturers' Issues

The manufacturers surveyed have experience with both military and civilian helicopters. The certification requirements for a full icing clearance for military and civilian helicopters are based on the same icing envelope, Appendix C of JAR-29.[4] However, military helicopters will have additional requirements that will have been dictated by mission objectives. Whereas civilian requirements concentrate on demonstrating that the helicopter is safe. Consequently, far more testing is carried out on military machines.

When helicopters are undergoing natural icing trials, it can take several winters to gain sufficient evidence for the certification regulations to be met. The flight performance and handling assessments are carried out by flying into known icing conditions, then accreting ice and carrying out the prescribed maneuvers. The helicopter operational procedures for flying in icing conditions are also determined from the natural icing trials flown for certification. These procedures are also developed using experience gained with other rotorcraft that are produced by the manufacturer.

Manufacturers were concerned about the accuracy of JAR-29 Appendix C icing envelope at altitudes of 10,000 ft and lower, and at temperatures close to 0 deg. This is of particular importance for helicopters because they cruise at or below 10,000 ft. Therefore, this part of the envelope is important and must represent real conditions accurately, and so, manufacturers would like to have Appendix C envelopes verified using current measurement instruments.

Susceptibility to Icing

When asked if there was a particular maneuver or phase of flight that caused problems, manufacturers stated that when a helicopter hovered in icing conditions, it can cause problems. This was because the maximum periodic icing conditions are not adequately covered for helicopters by JARs. Hover is a critical phase because, firstly, being close to the ground or water, means that there is little time for a recovery action if some unexpected event occurs. Secondly, during the transition from hover to forward flight, if any ice has been accreted on the rotors, it will be shed as the forces exerted on it rapidly alter with a change of in-flight phase. The shedding causes vibrations and can result in a degradation of handling. Furthermore, descending through an icing layer was felt to be more hazardous than climbing because the blades would already be cold from flying at cruise altitudes and, therefore, more likely to accrete ice. Helicopters do have to hover above off-shore platforms when landing or taking off, so this is a real concern for operators and manufacturers.

Manufacturers were asked about other weather hazards affecting helicopter operations. They replied that snow was more of an issue than in-flight icing, because if it enters the engine it can reduce engine power and, subsequently, less lift is developed, and in the extreme, a *flame-out* can occur. Manufacturers believed that wet snow, which seems to be more prevalent in Europe than in North America, should be included in Airworthiness Requirements.

The main factors that determine a helicopter's susceptibility to icing center on the main rotor blades, namely, their profile and flexibility. The material that they are made from and the surface finish have much less of an effect. This matter was confirmed during a refurbishment program. One manufacturer had replaced the original metal blades on a military helicopter with ones made from a composite material, and there was no noticeable change in the ice accretion or shedding characteristics. The assertion that profile matters was reinforced by the comments from one of the helicopter operators, who stated that the blades on the Bell 214ST were "quite broad and thick and seem resistant to ice accretion when compared to the thinner blades of the Super Puma."

When a helicopter has a full icing clearance, the main rotor is de-iced and the tail rotor is anti-iced. This de-icing is provided by electrically heated mats, which require a generator to produce the electric power. The weight of this extra equipment has implications for the load-carrying capacity of the helicopter, and additional maintenance is required, for example, for the electrical slip rings taking power to the mats. Furthermore, there are risks associated with accreting ice and then shedding it by using the de-icing mats. There were anecdotal reported incidents where ice had shed from helicopters and damaged the helicopter itself, or hit either oil platforms, airport structures, or personnel. Furthermore, until the ambient temperature is below $-5°C$, the tips of the main rotor blades will be heated sufficiently by kinetic heating, which avoids the need for de-icing.

Carrying out the necessary theoretical, ground, and natural icing trials for icing clearance certification is an expensive process and, in a commercial environment, such factors must be considered. Such costs would be passed on to customers as an increase in the purchase price of the helicopter. Therefore, although it is possible for manufacturers to provide civilian operators with a helicopter that can fly in icing conditions, this would result in a more expensive aircraft in terms of purchase price and maintenance and operational costs.

Ice-Accretion Prediction

Ice-accretion predictions are only carried out for those helicopters that require an icing clearance. The predictions are concentrated on the main and tail rotors and engine intakes. All the other surfaces of the aircraft are not normally regarded as critical for icing. Ice-accretion software is used to predict ice buildup on the two-dimensional aerofoil sections of the rotor. Once the critical ice shapes have been determined, models of the shapes are made and attached to blade aerofoil sections for testing in dry-air wind tunnels. These results are then used to predict the rotor performance in natural icing conditions and to design the ice-protection systems for the rotors. If the main rotor is fitted with ice-protection systems, the sequence and method of operation can also be simulated, using heat-flow models added to the ice-prediction codes. The activation sequence of the de-icing mats, which are normally chordwise, is a complex process to determine, and may be carried out from the tip to the center of the rotor blades or in the other direction.

It was clearly and repeatedly stated by manufacturers that, although computer predictions and wind-tunnel testing are improving all of the time, these are still only predictions and must be verified, using natural icing trials.

Ice Detection

Manufacturers stated that the best method of detecting ice accretion on the helicopter was by monitoring out-of-the-cockpit visual cues. Such monitoring should start once the outside air temperature (OAT) is less than 5°C and there is visible moisture in the area. The aircrews should be monitoring the following recommended visual cues: the central windscreen spar and accretion meter, windscreen wipers, sponsons, and door handles. These visual cues are supported by checking for any increase in the engine torque. Torque rise indicates that ice is accreting on the main rotor and reducing the amount of lift it produces. Therefore, to produce the same amount of lift, more power is necessary. This is shown by an increase in torque. The torque rise is regarded as the most accurate and reliable method of detecting ice and determining icing severity. Flying to a known torque rise is acceptable, provided it has been previously determined by the manufacturer. Typical acceptable increases of between 5 and 15% were stated by the different manufacturers and organizations surveyed. The actual permissible increases are specific to each helicopter type. Above this level the amount of power necessary to maintain handling and performance is both unsustainable and, in time, damaging to the rotorcraft. Ice accretion can also be felt as vibrations through the controls, fuselage, and sometimes, in extreme cases, by a reduced rate of climb.

To obtain a limited icing clearance certification, an ice indication system must be fitted. The two most commonly used are the hot-rod icing-rate meter and the liquid water content (LWC) instrument. LWC instruments have a problem with maintaining accuracy over the wide operating speed range of helicopters, but manufacturers feel that instruments are generally improving.

Typical examples of ice-indication systems are fitted to the following rotorcraft.

1) The Bell 214ST is fitted with a hot-rod ice-accretion meter directly in front of the cockpit windscreen. This instrument accretes ice over a timed period and is monitored by the aircrew. The rod is then heated and the ice melts. The helicopter can remain in icing conditions as long as the hot rod does not accumulate more than 1 cm of ice in 4 min of flying time, and that the torque does not increase by more than the permitted level. If these parameters are exceeded, then the helicopter must find less severe conditions.

2) The Eurocopter 332L is fitted with a Leigh detector (this unit is no longer in production; a unit with similar technology is made by Penny and Giles, Christchurch, UK). This instrument measures icing severity. It uses a double-walled tube, through which engine bleed air is directed to produce an induced airflow. Inside the tube an infrared diode is mounted, together with a phototransistor, which has proportional sensitivity. When air flowing through the tube contains supercooled droplets, they freeze inside the tube, the infrared beam is blocked by ice, and a signal is sent to the cockpit. The blocking of the beam triggers a heating cycle that melts the accreted ice. The time elapsed between two ice buildup periods is used to measure icing severity, which is displayed in the cockpit on an illuminated display.

Operators and Aircrew Issues

All of the operators interviewed, except for one, were off-shore operators, based around either the North Sea, in Europe, or off the coast of Nova Scotia in Canada. One Swiss overland operator was selected because its mountainous location provided a contrast to the off-shore operators.

The types of helicopter operated were as follows.

1) Eurocopter SA356-N2, Agusta 109K2, Sikorsky S76A/B, and Bell 206, 212, 412, with no clearance.

2) Sikorsky S61N and Bell 214ST, both with limited icing clearance.

3) Eurocopter SA 332L/L1/L2, with limited and full icing clearance.

The Eurocopter SA 332L is commonly known as the Super Puma, and the Eurocopter SA356N2 as the Dauphin.

Helicopters were typically used for 800–1000 h/year, and aircrews flew for 600–700 h/year. Pilots would often be rated on two types of helicopters, if flying for a company that had different types in its fleet. In off-shore operations, sector lengths were between 20 and 90 min, with helicopters normally only touching down on oil platforms for an exchange of passengers and cargo. Over the North Sea and Canada, each operator tended to fly to platforms on odd numbered altitudes and to fly return journeys using the even altitudes. All of the flights carried out in Switzerland were of an Air Ambulance type, and normally involved a 20-min flight to the patient, a 20-min flight to the hospital, and a 20-min return flight to the base.

None of the operators regarded in-flight icing as a major issue when compared with other adverse weather conditions. All operators averaged losing between three to four days flying a year to ice, whereas low visibility caused by fog, mist, and clouds presented a greater problem. Furthermore, low visibility can occur all year, whereas in-flight icing is normally seasonal, occurring mainly between November and February. The European operators were moderately concerned about snow. They commented that it seems to be wetter in Europe than in Canada and the U.S. Although, no evidence was presented to support this argument; however, all of the operators and aircrews supported this opinion. Snow causes visibility problems and can cause engine flameout problems if ingested in large amounts. To prevent this second problem from occurring, grills and shields are fitted in front of the engine and, according to operators, have prevented any incidents from occurring. The shield reduces the amount of air entering the engine and, subsequently, the level of power produced is also reduced. However, they are necessary to protect the engine from ingesting large amounts of water in the form of snow or slush. During the summer months the shields are removed to improve the efficiency of the engines.

At Nova Scotia in Canada, off-shore platform operations, which are very similar to those in Northern Norway, have been restarted after a 10-year gap. This is because economic conditions have now made their operation viable. Owing to the aviation world's paucity of helicopter operators with icing experience, the Canadian operator has leased three helicopters from a Norwegian operator. This is necessary because for several months of the year the sea around the coast can freeze. This means that the positive temperature layer often found over the sea is not available as an escape route from icing conditions. Thus, helicopters with a full icing clearance are required for this route.

Flying in Icing Without Clearance

Some operators and aircrews stated that, owing to commercial considerations, for brief periods they do fly in icing conditions, despite not having clearance. This is significant because it means that some helicopters can cope with icing conditions and that people are aware of this fact. Aircrews that were questioned further on this issue stated that: "we know the helicopter can cope with limited icing conditions because we have done it and we've spoken to other crews who have also flown in icing."

The crews felt that because they were using helicopters that had been given limited icing clearances by the UK's CAA, they must be comparatively safe for short periods and for average icing. When the aviation authorities were asked about this issue they did not accept that pilots sometimes fly in icing conditions. It was clearly stated that, when operators and helicopters did not have clearance, they would not operate in icing. In the opinion of the authors, it is expected that, as long as no incidents or accidents occur, the operators will persist in flying for short periods in icing without clearance.

Benefits of a Limited Icing Clearance

Operators would like the manufacturers to certify all helicopters for limited icing. Information such as permitted engine torque rise and escape procedures could then be provided to pilots who fly into icing conditions. In addition, they felt that manufacturers should notify operators of any severe handling problems with icing. Currently, pilots who fly in helicopters without an icing clearance only learn about problems with handling from other pilots and company internal communications. A further advantage of a limited icing clearance is that it allows helicopters to takeoff and climb through icing clouds at low altitudes, into conditions free of icing, or with limited icing. It also permits helicopters, which have inadvertently entered icing conditions, to remain on course, provided that they stay within the limited icing clearance parameters. The limited clearance gives greater operational capability to helicopter operators without significant additional cost associated with full icing clearance.

Operators accept that there are also disadvantages with a limited icing clearance. Pilots may stay in icing conditions for too long, and so compromise the safety of the helicopters. Also, there can be pressure from operators and fellow pilots to takeoff in icing conditions that are unknown or potentially unsafe because they are on the border of the clearance parameters. Furthermore, if ice is accreted, it will be shed and there are problems associated with helicopter performance and handling, particularly if the shedding is asymmetric.

Benefits of a Full Icing Clearance

Generally, off-shore operators felt that helicopters did not need a full icing clearance. This was because the increased costs associated with purchase, maintenance, and day-to-day operations would have to be recovered from clients, making it more difficult to be commercially competitive. However, overland operators did say that it would have significant advantages because of the difficulty in finding escape routes for limited icing clearances. If ice-protection systems were developed that did not have the operating penalties of current systems, then all of the operators stated that they would consider buying them.

Operating Procedures

Manufacturers provide all operators with information on how to detect ice and, subsequently, how it can be avoided. This information is included in the adverse weather section of the helicopter flight manuals. The operating procedures used by pilots to avoid icing tend to have been developed in-house by operators and are then subsequently approved by the country's certifying authority as part of the operator's license.

The interviewers were repeatedly informed that aircrews do not deliberately enter icing environments, but prefer to have flight plans that avoid icing. This measure includes helicopters that have limited clearance. This statement is in contrast to that described earlier, where pilots stated that, on occasion they remain in icing conditions, despite having no clearance.

It would appear that it is entirely a pilot's decision that determines whether a helicopter will enter or remain in icing. The decision seems to be based on the type of helicopter being flown, the geographic location, and the pilot's knowledge, experience, and confidence. There can be company pressure to fly, particularly if a helicopter from a competitor's company has already taken off. However, all operators and aircrews maintained that it was each individual captain's decision whether to takeoff or not.

When a UK-operated helicopter encounters in-flight icing, the captain of the aircraft must write an icing report for their organization and the CAA. This is a mandatory occurrence report and is part of the limited icing clearance certification process.[8] None of the other European helicopter operators nor those in Canada mentioned such a reporting system.

Most Severe Conditions

Operators stated that they regarded in-flight icing at low altitudes, between 1000 and 5000 ft, as the most dangerous. This is because, if ice accumulates quickly and the helicopter suffers from a rapid loss of handling and performance, including a loss of lift, the pilot may only have a couple of minutes to prevent the helicopter from crashing. However, this contrasts with the manufacturers' icing specialists who stated that for any given icing condition, for example, excessive control loads, blade stall and torque rise are all aggravated as altitude increases. Helicopter icing is generally more severe at 10,000 ft than at 1000 ft. Operators probably consider icing at lower altitudes more dangerous because most of those interviewed were in the off-shore environment and they very rarely cruise above 5000 ft and, therefore, do not have the experience of icing at higher altitudes. This would appear to be an area where the manufacturing part of the industry has a greater knowledge than the aircrews and operators, and an area where some training should be carried out.

Aircrew and Ice Detectors

All operators and aircrews felt that the pilot was the best ice detector and the best method of detection was to monitor the previously described visual cues. If pilots are concerned about the level of icing, they must leave the conditions before the performance, handling, and safety of the helicopter are compromised. Aircrews operating helicopters with a limited icing clearance regard torque rise and the icing-rate meter as the best indicators of icing levels. To prevent inadvertently entering icing, pilots are required to avoid long periods of flight in clouds. However, it is sometimes difficult at night to see clouds before entering them, and so on such occasions other cues are beneficial, namely the windscreen wiper and, if fitted, ice detectors. In reality, helicopters would benefit from being fitted with an ice predictor, which warns pilots of impending icing conditions and gives them time to activate ice-protection systems.

Finally, aircrews stated that freezing rain can be a problem because the ice-protection systems may not be able to cope with the rapid accretion of ice. The scale and frequency of the occurrence of freezing rain was not available from the operators or aircrews. For European operators, although it is a problem, it is not a major issue for them because it rarely occurs in that area. However, in Canada, operators encounter freezing rain more often and, currently, when it occurs they cannot takeoff until it passes. If encountered in flight, they must divert or, if this is not possible, land.

Training

Manufacturers do not provide specific training packages for the operators in winter operations. Operators have produced their own material, abstracting information from flight manuals and other sources. Operators stated that they want more information from manufacturers on coping with adverse weather.

Aircrews' awareness of the possible hazards are assessed during six monthly check-rides, which are conducted by training captains and instructors. There is an opinion that experience and knowledge of icing among some of the younger pilots is low and that sometimes they are inclined to take risks and fly in conditions that are dangerous. However, no evidence was provided to support this statement. Pilots gain the experience of icing conditions by flying as copilots with experienced captains for typically 4 to 5 years.

All aircrews also receive winter-operations training each winter, where they are reminded of the hazards associated with adverse weather conditions and cold-temperature flying. In addition, during the check-ride closest to the winter, the assessing instructor often includes icing exercises. However, these exercises are far less extreme than those that could be practiced on a simulator. There are few helicopter simulators available and none have a full icing model. Operators claimed that they would use simulators with icing models, if available, at convenient locations.

Weather Forecasts

Interviewees would like to be able to track the path of weather, to see the direction in which it is moving. This would allow better route planning. It is common for ice to be forecast for a specific location and, when a helicopter reaches the location, to find that there is no ice. Furthermore, the ice often occurs in locations where it is not predicted. However, because aircrews regularly monitor the visual icing cues, the OAT, and the torque meter during the flight, they are ready for the occurrence of icing. If ice is forecast, or if there are reports from local weather stations that predict ice of a severity greater than the icing-clearance parameters, then helicopters will not take-off.

If pilots encounter in-flight icing that has not been forecast, this is communicated to other helicopters in the area, to air traffic control, and to the operator's flight-operations department. It is a beneficial activity, because it can prevent aircraft from inadvertently entering icing conditions.

Ground Icing Issues

All of the operators stored their aircraft in hangars overnight, this negates any problems with ground icing and, consequently, it is very rare for operators to use de-icing fluids. A further reason for their infrequent use is that helicopter manufacturers do not recommend the use of de-icing fluids. The rotor blades and parts of the fuselage could be damaged if they are made of composite materials such as carbon fiber and Kevlar.® The effect of the de-icing fluids on these materials is unknown. There is also the danger that fluids could get ingested by the engines and cause problems. Ground icing can be an issue for helicopters, if they are unable to takeoff from a platform and left out overnight. Most platforms have no de-icing fluids, and so, if helicopters do have ice on them, they have to wait for it to melt before taking off.

Recommendations

It is recommended that the priorities for helicopter icing research and development activities should be in the following areas.

1) To improve the ice-prediction codes by improving the thermodynamic modeling and to verify the model for typical helicopter operating conditions. This should permit more accurate ground testing and prediction of critical ice shapes.

2) To find alternative methods of ice protection for rotors that do not require large additional power sources to be installed. It will then be possible to provide all helicopters with the same protection as other commercial aircraft.

3) To develop an ice-prediction probe, which warns helicopter aircrews that they will soon be entering icing conditions. This contrasts with current probes and detectors that only inform the aircrew that they are already in icing conditions.

4) To improve pilot training by increasing the fidelity of the icing model on helicopter simulators and ensuring that aircrews have access to them.

5) To verify that the icing atmosphere of Appendix C[4] is representative of helicopter operating altitudes.

Conclusions

The majority of the operators surveyed in this project were off-shore operators who, owing to the warm temperature layer found over the North Sea, do not need full icing clearances on their helicopters. However, operators would like to have a limited icing clearance on all of their helicopters because it would allow them greater operational capability. Operators are not interested in a full icing clearance until alternative means of ice protection are developed that do not have significant cargo and maintenance penalties.

The regulations and methods used to certify helicopters have been adapted from those of fixed-wing aircraft. Considering that helicopters routinely operate at lower altitudes than fixed-wing aircraft, then it would be beneficial to the aviation industry to ensure that the parameters used in the certification, namely Appendix C, are valid.

Acknowledgments

This work was funded by the Commission of the European Communities, Directorate General for Transport—DG VII.

The authors of this report would like to take this opportunity to thank all those individuals, companies, and organizations who have helped throughout this project. It was only through their cooperation, generosity, and help that the project was made possible. We would also thank J.-F. Boer at the National Aerospace Laboratory, The Netherlands, for his help with the survey and data analysis. None of the results or comments are attributed to any organization or individual.

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