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Helicopter Downed in North Sea after Lightning Strike Exceeds Lightning-protection System Capabilities

A tail-rotor imbalance was caused by lightning damage to one of the carbon-composite tail-rotor blades. The resulting vibrations induced a dynamic response in the tailboom until the tail rotor and the tail-rotor gearbox separated from the aircraft.

FSF Editorial Staff

On Jan. 19, 1995, a British-registered Aérospatiale (now Eurocopter) AS 332L Super Puma (Tiger), operated by Bristow Helicopters Ltd., was on a charter flight, ferrying 16 maintenance engineers from Aberdeen, Scotland, to the Brae "A" oil-rig platform in the North Sea.

The aircraft was scheduled to stop en route at the East Brae platform to pick up two more engineers. During a descent from 915 meters (3,000 feet) mean sea level (MSL) to the East Brae platform, the aircraft passed through clouds. While in the clouds, occupants of the helicopter described hearing a large bang that was accompanied by a flash of light, after which the helicopter began vibrating severely. Three and one-half minutes later the tail-rotor gearbox separated from the helicopter. The aircraft was ditched in high seas with no fatalities.

The official U.K. Air Accidents Investigation Branch (AAIB) report said that the causal factors of the accident were "(1) one of the carbon-composite tail-rotor blades suffered a lightning strike which exceeded its lightning-protection provisions, causing significant damage and mass loss; (2) the dynamic response of the gearbox/pylon boom assembly to the tail-rotor system imbalance induced rapid cyclic overstressing of the gearbox attachments, which was accelerated by the early failure of the upper mounting-bolt locking wire, allowing consequent loosening and fatigue failure of this bolt; (3) complete loss of the yaw control system and a momentary pitch-down as a result of detachment of the tail rotor, [tail-rotor] gearbox and pitch-servo assembly; [and] (4) the lightning-strike protection provisions on this design of carbon-composite tail-rotor blade were inadequate due to it having been developed from an earlier fiberglass blade which had been certificated to lightning-test criteria which have since become obsolete."

The first officer was the pilot flying when the helicopter took off at 1138 hours local time. At 1233, the crew informed Aberdeen Flight Information Service that they were at the reporting point for the East Brae platform, their first destination, and changed frequency to Brae Traffic Watch (Brae). Lightning struck the aircraft as it began its normal descent. Although the lightning that struck the accident aircraft was unexpected, "the crew correctly identified the problem and acted promptly," said the report.

Because of the heavy vibrations felt immediately after the lightning strike, the first officer transmitted a Mayday call on the Brae frequency and began an autorotation.

After initiating an autorotation, the crew discovered that, despite the severe vibrations, the aircraft was controllable. The report said, “This introduced another potential problem, i.e., whether to alight on the sea beside the platform, or whether to attempt landing on the platform.”

The report said that operating crews often have an understandable reluctance to ditch voluntarily because of the aircraft’s potential to roll and sink. Nevertheless, the degree of vibration produced by a tail-rotor imbalance can be so severe that in a very brief period the tail-rotor assembly and associated gearbox can detach from the helicopter.

“The dilemma facing a commander, in such a situation, is therefore whether to ditch and risk loss of life, or to attempt a landing on a platform hoping that the tail rotor and gearbox will not detach [while] the helicopter is approaching the helideck [with] of the added stresses induced by the necessary changes in torque. The consequences of such an occurrence could be catastrophic due to the accompanying loss of yaw [control] and pitch control.”

The crew leveled the helicopter and flew toward the Brae “A” platform, the nearest landing site.

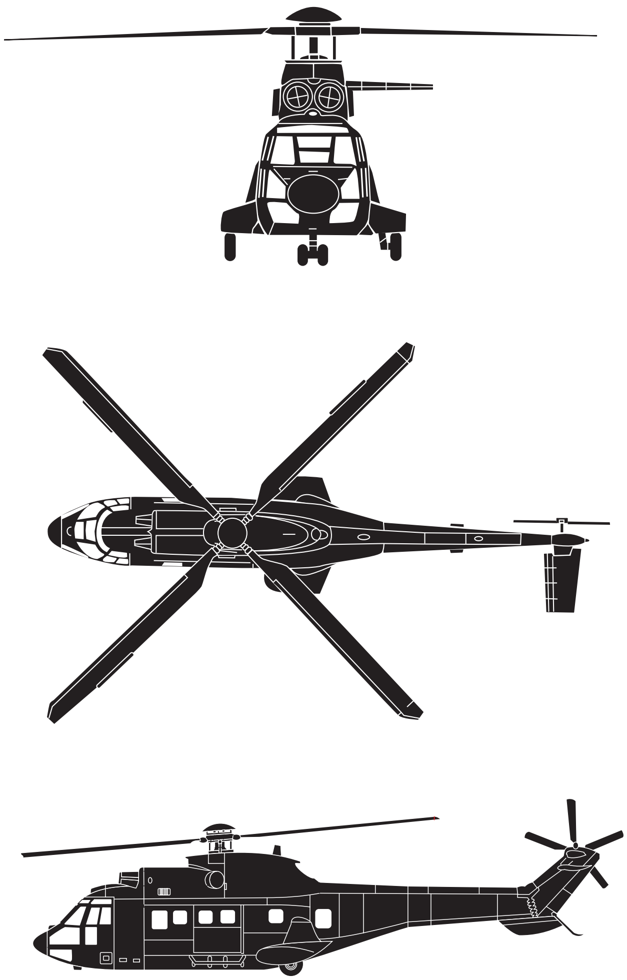
The first officer tested the yaw pedals for response to determine if the tail rotor was effective, or if the apparent directional stability of the helicopter was caused by the aircraft’s forward airspeed, allowing the aircraft to weathercock into the relative wind. After the first officer commented to the aircraft commander that the pedals seemed to work, the report said, “there was a ‘crack’ and the helicopter gave a violent lurch to the left, rolled right and pitched down steeply.” The tail-rotor gearbox had separated from its mountings.

The first officer regained control of the aircraft, and the aircraft commander executed the emergency procedures, shutting down both engines and deploying the aircraft flotation equipment.

The first officer ditched the aircraft, landing gently despite six-meter to seven-meter (20-foot to 23-foot) seas and a 56-kilometers-per-hour (kph) (30-knot) wind.

All 16 passengers and the two crew members evacuated safely. Although the aircraft was equipped with two rafts, the raft on the left side of the aircraft was blown onto its edge, with its floor against the fuselage. Realizing that this raft would be difficult to use, and in an effort to accomplish the evacuation quickly, the first officer decided that all occupants should board the 14-man raft already deployed on the right side of the aircraft.

The Super Puma’s doors are constructed of composite material skins separated by a low-density core and will float, perhaps indefinitely, after being released. When the passengers jettisoned the main-cabin doors in rough sea conditions with the aircraft rolling through a large angle, the bottoms of the doors hit the water. Because they are buoyant, the doors did not continue to fall away from the aircraft vertically. Rather



Aérospatiale (Eurocopter)
AS 332L Super Puma (Tiger)

The Aérospatiale AS 332L has a four-bladed fully articulated main-rotor system that can be stopped by a hydraulically operated rotor brake within 15 seconds of engine shutdown. The five-bladed tail rotor has flapping hinges only and is located on the right side of the tailboom. The aircraft is equipped with retractable landing gear. The Tiger model is fitted with 19 passenger seats, a public address system, an automatic emergency-door jettison feature and large-capacity life rafts.

The prototype of the Super Puma flew for the first time in September 1978 and the AS 332L version of the Super Puma flew for the first time in October 1980.

The AS 332L has a never-exceed airspeed of 278 kilometers per hour (150 knots) and a service ceiling of 4,600 meters (15,090 feet). Maximum normal takeoff weight is 8,600 kilograms (18,960 pounds). The aircraft has a range of 842 kilometers (523 miles) with standard fuel tanks and no reserves.

Source: *Jane’s All the World’s Aircraft* than disengaging freely from the aircraft, both of the left-main door's and one of the right-main door's upper attachment points broke, exposing jagged edges.

The occupied raft contacted a jagged projection on the edge of a floating jettisoned door and one of the raft's buoyancy chambers was punctured, but the raft continued to float.

During the wait for rescue, although protected from exposure to the water and cold temperatures by anti-exposure suits and the life raft, survivors were unable to properly raise the raft's canopy or to locate the equipment bags containing the paddles and bailer.

About an hour after the accident, "the crew and passengers were recovered from the raft by the fast rescue craft of two oil platform safety vessels," said the report. The helicopter was temporarily tethered alongside a third safety vessel, but sank several hours later after the rest of its flotation bags were punctured. The helicopter was recovered later for examination.

The helicopter's combined voice and flight data recorder (CVFDR), which had been operating prior to the lightning strike, stopped recording at the time of the strike.

"It was determined that the recorder had lost its power supply as a result of operation of the G-switch due to the level of tail-rotor vibration induced by the lightning strike," said the report. "Electrical power was cut to the CVFDR sufficiently quickly that the audio effects of the lightning strike were not recorded on the audio tracks of the CVFDR."

The aircraft commander had an airline transport pilot (ATP) license (helicopters) with 9,610 hours of flight time, and 4,695 hours in type. The first officer also had an ATP and had 3,158 hours of flight time and 2,593 hours in type.

The AS 332L is a conventional helicopter with articulated main- and tail-rotor heads, and is equipped with four composite main-rotor blades and five composite tail-rotor blades. The main element of the lightning-protection system is an antierosion shield on the leading edge of each main- and tail-rotor blade.

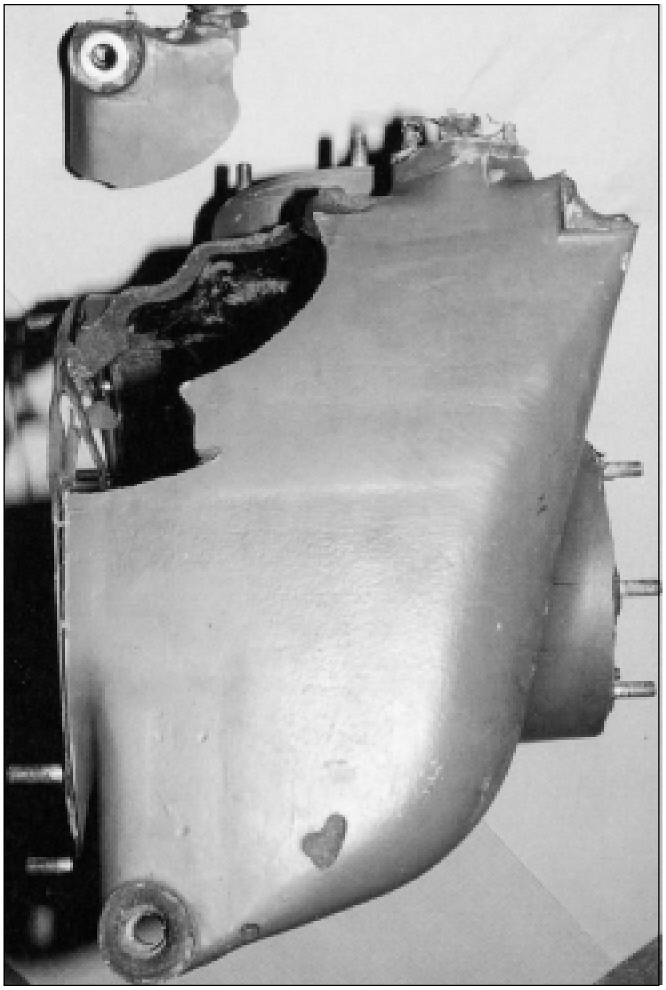
Detailed examination of the wreckage showed that two of the four main-rotor blades suffered lightning damage but continued to operate satisfactorily. Four of the five tail-rotor blades were damaged in a manner "consistent with the effect of the blades striking the pylon after the gearbox had separated," said the report. Significant lightning damage was evident on the fifth tail-rotor blade. Each tail-rotor blade is marked with a different color for identification. The report said that the white blade "suffered marked delamination of its composite skins and associated thermal damage of its root areas, together with loss of its antierosion shield, brass conducting strip and failure of the braided bonding strap and its attachment lug to the blade bolt [photo, top right]. …

The damaged inboard (left) side of the white tail-rotor blade shows thermal delamination of the root area and general delamination outboard, including delamination of the leading edge from which the antierosion shield detached. (Photo: U.K. Air Accidents Investigation Branch)

"Examination of the tail-rotor gearbox/pylon area confirmed that the gearbox had separated as a result of failure of the magnesium alloy gearbox casing at, or close to, the lower attachment points, in addition to failure of the upper attachment bolt [photo, page 4]."

The tail-rotor lightning-protection system of the AS 332 series is almost identical to that designed for the earlier model Aérospatiale AS 350 Ecureuil. The AS 350 was originally certificated according to the then-current lightning-protection standard, Transport Supersonique Standard (TSS) 8.6.

The report said, "[The TSS 8.6] standard incorporated a general reflection of nationally accepted practices then current … and as such was evolved approximately coincidentally with the earliest certification criteria (in the West) to incorporate specific numerical lightning protection criteria, as opposed to the earlier simply stated requirement that all elements of the aircraft must be effectively bonded. … [The] TSS 8.6 standard document



Failure of lower gearbox attachments was caused by excessive vibration and led to separation of the tail-rotor gearbox from the tailboom. (Photo: U.K. Air Accidents Investigation Branch)

called for a single pulse of 200 kiloamps (kA), with an action integral [a measure of the total energy deposited or absorbed in a system expressed in a quantity which can be used in reference to any material, regardless of its resistance] of 0.6 x 10^6 Ampere^2 second (A^2s) and a charge transfer of 500 coulombs, to be applied experimentally to areas of the aircraft structure without inflicting significant damage."

An important difference existed between the AS 332 and AS 350 that was not accounted for in the design process. AS 350 tail-rotor blades were made of glass-reinforced plastic (GRP), but the AS 332 tail-rotor blades were made of carbon fiber–reinforced plastic (CFRP).

"CFRP differs electrically from GRP in being a series of fine conductors (the carbon fibers) embedded in an insulating material (the matrix) rather than being a total insulator with nonconductive glass fibers embedded in a nonconductive matrix," said the report. "It is therefore possible for lightning attachments [contact of the main channel of a lightning flash with the airplane] to occur to carbon-composite areas of such blades under conditions where lightning attachments would not occur to corresponding points on geometrically similar blades manufactured from GRP."

More stringent lightning-protection criteria had been recommended by the U.S. Federal Aviation Administration (FAA) since the certification of the AS 350. The report said, "This design of carbon-composite tail-rotor blade was not subjected to lightning testing during its certification in 1981 for the AS 332 Mark 1 helicopter, since it was considered merely a development of an earlier fiberglass blade fitted to the AS 350 Ecureuil, which had been satisfactorily certificated to the lightning-test criteria of TSS 8.6 … ."

Although the tail-rotor blades on the accident aircraft were constructed using carbon-fiber materials, they differed from the original design on the AS 332L. The tail-rotor blades on the accident aircraft were constructed of a skin combining one layer of fiberglass and two layers of carbon-fiber cloth over a foam core (Figure 1). The modified design was used on all AS 332s flown by U.K.-based North Sea operators, as a remedy for poor foreign object damage–resistance characteristics of the original CFRP blades.

In 1967, TSS 8.6 was superseded by FAA Advisory Circular (AC) 20-53, and in 1985 by AC 20-53A.

Composite Tail-rotor Blade on Accident Aérospatiale (Eurocopter) AS 332L

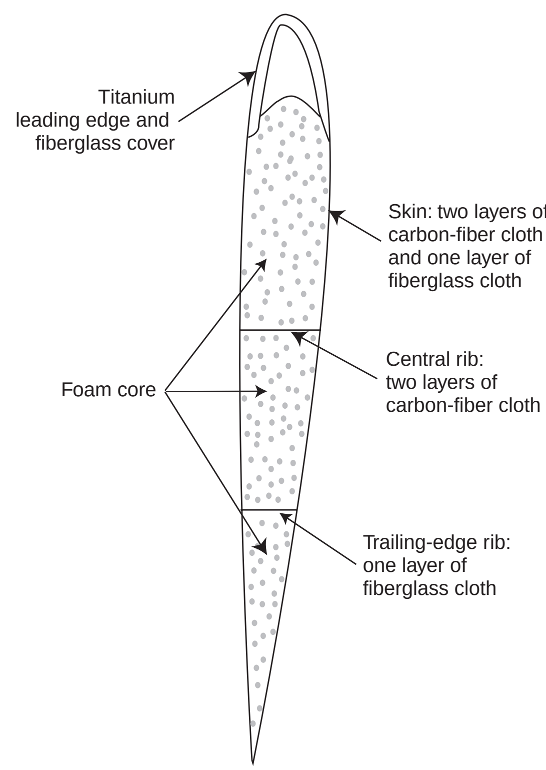


Figure 1

The report said that use of AC 20-53A criteria by manufacturers to achieve lightning certification is purely advisory. Suggested testing procedures represent just one acceptable means with which to comply with regulations aimed at preventing ignition of fuel vapors in the event of a lightning strike to fixed-wing aircraft.

AC 20-53A recommends that lightning-protection systems be tested using an action integral of $2x10^6A^2$ s for Zone 1A. Zone 1A is defined as part of the direct-strike zone, specifically the leading edges or forward extremities of the nose, wing and empennage tips, wing-mounted nacelles and other significant projections.

AC 20-53A criteria do not address differences in the conductivity of various structural materials, nor do they address the complexities brought about by rotational movement of the blade in flight. Application of a current pulse to a point on a fixed blade is not a valid representation of lightning striking a rapidly revolving blade. Suggested test methods have therefore failed to properly model current flow through the blade-attachment pins and any associated composite structural damage.

When aircraft were primarily of metallic construction, the conductivity of the aircraft materials was far greater than that required to limit thermal damage in all but a few isolated parts of the aircraft structure.

"The advent of modern aircraft having large amounts of composites in their primary structures and critical components has elevated the significance of lightning-testing criteria … ," said the report.

Lightning resulting from cumulo-nimbus activity usually begins as discharges within and between clouds. After five minutes to ten minutes of this type of activity, cloud-to-ground discharges often begin.

The report said, "These [cloud-to-ground] discharges tend to be negative (i.e., where associated cloud is negatively charged with respect to ground) in or near the rain shaft area, negative or positive further outwards, with isolated positive discharges occurring well away from the storm centers, usually descending from the developed storm 'anvils'. … This information is based on 'over-land' observations and the extent to which the same sequence occurs over the sea appears less known. …

"During aircraft operations, a majority of strikes occur in cloud and it is generally accepted that most of these are 'triggered' by the presence of the aircraft in the cloud electric field. Thus the intra-cloud and inter-cloud types of strikes can affect aircraft early in the development of a storm without any previous discharges in the cloud system and before a well-defined cumuloform cloud develops.

"Positive strikes are, on average, much more powerful than negative strikes. This is largely because they are of longer duration, resulting in a considerably larger action integral. Thus the decision upon whether to include, or exclude, positive strikes makes a marked difference in the levels of any proposed certification criteria."

Current AC 20-53A standards require that the aircraft's lightning-protection system be capable of handling 98 percent of the negative cloud-to-ground or cloud-to-sea strikes encountered.

"The remaining two percent of strikes [would be] accepted as inflicting severe, but undefined, damage," said the report. Positive strikes are not addressed in AC 20-53A.

Nevertheless, based on a data sample gathered during 1990, an estimated 80 percent of lightning discharges in the North Sea area were positive. Based on this data, researchers estimated that 30 percent of cloud-to-sea strikes in the North Sea area may exceed the AC 20-53A certification criteria.

The report said that lightning data are available for North Sea pilots during the planning stage of a flight. The data are relayed from an automatically located atmospheric discharge (SFERIC) system to air traffic control (ATC) through a meteorological office. This relay process creates a delay of 15 minutes to 20 minutes between the actual lightning discharge and the report to ATC.

The report said that preflight weather briefing for the first half of the flight to the Brae oilfield was, "visibility 30 kilometers [19 miles], one to three oktas of cumulus (Cu) and stratocumulus (Sc), base [763 meters] 2,500 feet and tops [1,525 meters] 5,000 feet, moderate turbulence and moderate icing; isolated conditions of eight kilometers [five miles] visibility in rain showers, or rain and snow showers, with six to seven oktas Cu, base [458 meters] 1,500 feet, tops above [3,050 meters] 10,000 feet.

"For the remainder of the flight to Brae, the forecast was: visibility 30 kilometers, two to five oktas CuSc, base [610 meters] 2,000 feet [and] tops [1,830 meters] 6,000 feet, moderate turbulence and moderate icing; occasionally six kilometers [3.7 miles], rain showers or hail, rain and snow showers, with seven to eight oktas Cu, base [458 meters]; occasionally 1,500 meters [4,922 feet] visibility, hail and snow showers, with eight oktas stratus with embedded cumulonimbus (Cb), base [214 meters] 700 feet [and] tops above [3,050 meters]; isolated thunderstorms with eight oktas Cb, base [458 meters] and tops above [3,050 meters].

"General sea state: moderate in the south, very rough in the north."

"Once airborne and flying between cloud layers, there was nothing indicated on the weather radar which would have been likely to have caused the crew any problem," said the report. "Although [the crew] commented, on the CVR, about a large cloud build-up to the north of their track … they still had a generally clear passage to their destination. The lightning strike was therefore totally unexpected, particularly as they were flying in an area where their radar had not shown any significant storm clouds."

Because the SFERIC system requires 15 minutes of processing time before the lightning-discharge information is made available to pilots, aircraft-mounted lightning-detection equipment has been advocated in recent years.

The report said, "All [lightning-]warning systems currently in use, whether land-based or aircraft-mounted, rely on the pre-existence of lightning discharges to give warning of the danger to aircraft flying in the vicinity of the lightning activity."

For example, the report said, "[Stormscope-type aircraft-mounted] equipment detects electrical discharges, whether visible or not, by analyzing the associated radiated electromagnetic signals, for both azimuth and range, and displaying each detected discharge on a cathode ray tube (CRT) display."

Because many lightning strikes within and between clouds are thought to be triggered by the presence of an aircraft in the charged air mass, many of these strikes cannot be predicted. Work has been done to develop an airborne electrical field (E-field) meter that can detect the increase in atmospheric voltage potentials that occur before lightning strikes. Nevertheless, in November 1996, E-field sensor research and development was halted by loss of funding.

After the accident, tests were conducted that simulated lightning strikes of various energy levels on tail-rotor blades in an attempt to recreate the type of damage suffered by the accident aircraft's white tail-rotor blade root.

The report said, "It is … considered beyond dispute that the white tail-rotor blade was struck with a high-energy lightning strike which was well above the AC 20-53A certification level. … The white tail-rotor blade may have suffered a lightning strike with an action integral of $6 \times 10^6 A^2s$, … three times the certification level advised in AC 20-53A, [because] the maximum action integral of $4.2 \times 10^6 A^2s$ attained during the tests produced root damage similar to, but less than, that apparent on the white blade. …

"As a result of early information gained from the investigation and lightning testing, Eurocopter developed a modified tail rotor-blade design … and the new blades (certificated to AC 20-53A requirements) were made available to AS 332L operators towards the end of 1995."

These new blades incorporated a titanium antierosion shield/conductor that extends inboard to the blade root and outboard to the blade-tip area (Figure 2). The titanium shield is riveted to the blade tip to provide positive retention if debonding occurs as a result of a lightning strike.

Original and Modified Tail-rotor Blades, Aérospatiale (Eurocopter) AS 332L

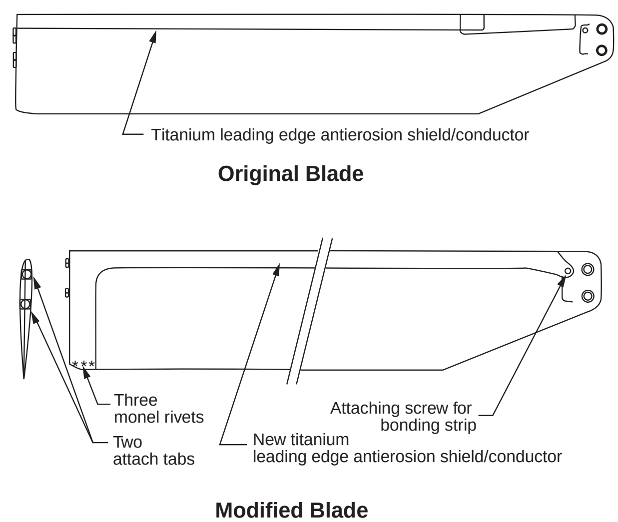


Figure 2

The report said, "This modified blade also included a fiberglass layer around the leading edge, i.e., underlying the erosion shield, and a new braided bonding strap between the root earthing bolt and hub."

Although tail-rotor blade damage could be simulated in the laboratory, even the highest-energy simulated lightning strikes had no significant effect on the tail-rotor gearbox attachment bolts.

"It was therefore decided to conduct a stress analysis of the tail and associated gearbox casing in an attempt to quantify the tail rotor out-of-balance force which would have been required to fail the gearbox attachments within the estimated three-and-a-half-minutes time scale," said the report.

A computer model–based flutter analysis of the tail-rotor blade determined that a much greater degree of structural damage than that produced in the simulated lightning tests would be required to create blade flutter or resonance.

A mathematical analysis determined that it would take a greater mass loss than that represented by the loss of the titanium antierosion shield to create stresses large enough to cause the tail-rotor gear box to separate solely because of loss of lift.

Further testing included using a spin-rig to determine if rotor blades damaged in a manner similar to the white tail-rotor blade from the accident aircraft would produce significant damage under continued operation. The tests did not produce further significant damage.

A final stress analysis was conducted that considered the dynamic response of the pylon/tailboom assembly.

The report said, "This dynamic analysis … indicated that the tailboom/pylon assembly would indeed have produced dynamic responses within the tail-rotor revolutions per minute range which would have accentuated the stresses on the gearbox mountings so that a very much reduced mass imbalance of the tail rotor, equivalent to the loss of the titanium antierosion shield, would have induced failure of the mountings within the required time scale of some three-and-a-half minutes."

The dynamic analysis also showed that the dynamic response caused by the loss of an antierosion shield on one of the tail-rotor blades would generate forces large enough to trigger the G-switch, interrupting power supply to the CVFDR.

"Examination of the fractured bolt from the upper attachment of the gearbox revealed conclusive evidence that the bolt had been slack at the time of its failure, having rotated [while] under cyclic loading and having then failed due to a cyclic bending load," said the report. "Examination of another AS 332L aircraft confirmed that the wire-locking of the three attachment bolts was of a very light gauge, unlikely to provide an effective restraint to rotation under excessive vibratory loads. …

"The failure of the locking wire attached to the upper attachment-bolt head and consequent loosening of this bolt, as a result of the cyclic forces induced by the tail-rotor out-of-balance condition, increased the loading on the two lower mounting lugs both by load transfer and by altering the natural frequency of the tailboom–pylon assembly … .

"It is also clear that the close proximity of the natural frequencies of oscillation of the tailboom to the range of tail-rotor rotation speeds used in normal flight and during autorotation had a critical effect on the short time between the lightning strike and the separation of the gearbox."

The report concluded with eight safety recommendations. Some of the recommendations were made prior to the publication of the report, and responses from the CAA or manufacturer were included in the report:

- "The CAA should ensure that the North Sea helicopter operating companies include, in their very effective recurrent training for crews, discussion and, where possible, hands-on practice of the procedures necessary to accomplish a successful evacuation from a floating helicopter following a ditching or alighting on the sea;

- "The manufacturer of the AS 332L Super Puma helicopter should review the failure modes of the cabin door upper guide-roller mounting arms which can occur during door jettison in rough sea conditions, and take action to prevent such mounting-arm failures, which can puncture [rafts] when they subsequently come into contact with floating doors."

  Eurocopter responded: *"We have never been faced with this anomaly on jettisoning the sliding doors, and all the tests conducted to date confirm this. Nevertheless, we are going to check that it is still possible to jettison the doors in the most severe operating conditions without this type of failure occurring"*;

- "The CAA should call for a survey of jettisonable doors, of composite construction, fitted to North Sea public transport helicopters to determine if they are initially buoyant on jettison and, if so, to inspect such doors for projections likely to puncture floating [rafts], taking into account damage likely to occur to door mountings during jettison in rough sea conditions;

- "In order to prevent the premature cessation of electrical power supply to helicopter [CVFDRs] caused by abnormal excessive vibration effects on associated G-switches, it is recommended that the CAA:

  "1. Require operators to render inoperative CVFDR G-switches, as an interim measure; and,

  "2. Take action to identify a more suitable method of stopping such flight recorders during crash impact."

  The CAA responded: *"The [CAA] would not be able to accept item 1 of this recommendation since such action may allow some recorders to continue running after an accident resulting in a crash impact, thus erasing the recorded data"*;

- "To provide helicopter commanders with the necessary real-time information to enable them to avoid flight into areas of actual thunderstorms or lightning activity in public transport helicopters which have composite rotor blades, the CAA and affected operators should jointly agree to the fitment of lightning-discharge mapping systems to such aircraft. The [CAA] should also inform other airworthiness authorities of the action taken in response to this recommendation."

  The CAA responded: *"Although the [CAA] would agree that an airborne lightning-sensor mapping system may provide some benefit as a supplemental aid for North Sea helicopter operations and may lower the chances of a lightning-strike attachment, there can never be any guarantee of this and it remains the case that adequate lightning-protection provisions must be installed on the helicopter. The [CAA] would therefore have difficulty in justifying mandating the installation of lightning-mapping systems for airworthiness certification purposes"*;

- "The manufacturer of the AS 332L Super Puma helicopter should introduce improved-strength locking arrangements for the mounting bolts of the tail-rotor gearbox assembly such that unlocking and loosening of these bolts does not occur under conditions of excessive tail-rotor vibration resultant from tail-rotor damage."

Eurocopter responded: *"The analyses carried out subsequent to the [Jan. 19, 1995] accident have led us to design a modification which improves the strength of the gearbox on the tailboom. This modification, … was approved on April 14, 1997, and proposes the installation of a bolt made from a new material and an optimized tightening torque load. This modification will be presented to our customers by Service Bulletin no. 64.00.24, classified 'Recommended'"*;

- "The manufacturer of the AS 332L Super Puma helicopter should review the dynamic frequency responses of the tailboom–pylon assembly in relation to tail-rotor rotational frequencies, with a view towards assessing the practicability of modifying the tailboom–pylon assembly to reduce associated structural dynamic coupling and related fatigue damage which may arise from in-flight tail-rotor blade damage/loss of mass."

Eurocopter responded: *"The test results obtained from the modeling carried out by Stirling Dynamics … are currently being analyzed by our engineering department. Once this analysis is completed, if tests are to be undertaken, this will most certainly be done with the participation of Stirling Dynamics"*; [and,]

- "The CAA, in conjunction with the appropriate industry committees, should review aircraft lightning-certification requirements, and the advisory nature of AC 20-53A, to introduce the following more stringent requirements for rotary-wing aircraft with composite rotor blades:

"1. Increase the specified Zone 1A action integral from 2 x $10^6 A^2 s$ to a level compatible with the highest-energy positive-polarity lightning discharges likely to be encountered in service;

"2. Replace the existing 98 percent probability assurance with 100 percent probability target;

"3. [Add] specified arc attachment points to be used in the lightning-certification tests on rotor blades, to include: leading-edge tip; tip weight bolt(s) if used; trailing-edge tip; trailing edge up to 0.5 meter [1.6 feet] inboard of the tip; [and,]

"4. Specify use of representative blade-root attachment assemblies during all lightning tests to simulate related current flow/thermal [effects] on root structure.

"In addition, the CAA and appropriate committees should review lightning-certification requirements with regard to any corresponding, or other, improvements which may be deemed necessary for fixed-wing aircraft with significant composite material structural elements."♦

Editorial note: This article was adapted from *Report on the Accident to AS 332L Super Puma, G-TIGK , in North Sea 6nm Southwest of Brae Alpha Oil Production Platform on 19 January 1995.* Aircraft Accident Report no. 2/97, prepared by the U.K. Air Accidents Investigation Branch. The 92-page report contains illustrations and appendixes.

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