Accidents Investigation Branch

Department of Transport

Report on the accident to Aerospatiale AS 332L G-TIGD at Aberdeen Airport, on 4 July 1983

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Department of Transport
Accidents Investigation Branch
Royal Aircraft Establishment
Farnborough
Hants GU14 6TD

14 January 1985

The Rt Honourable Nicholas Ridley
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr K P R Smart, an Inspector of Accidents, on the circumstances of the accident to Aerospatiale AS 332L G–TIGD which occurred at Aberdeen Airport on 4 July 1983.

I have the honour to be
Sir
Your obedient servant

G C WILKINSON
Chief Inspector of Accidents

Contents

Accidents Investigation Branch

Aircraft Accident Report No. 4/84
(EW/C838)

Registered Owner:	Bristow Helicopters Ltd
Operator:	Bristow Helicopters Ltd
Aircraft: Type:	Aerospatiale
Model:	AS 332L Super Puma (Tiger)
Nationality:	British
Registration:	G–TIGD
Place of Accident:	Aberdeen Airport Latitude 57° 12′ 20″ N Longitude 002° 11′ 50″ W
Date and Time:	4 July 1983 at 1217 hrs
	All times in this report are GMT

Synopsis

The accident occurred during a routine flight from the North-West Hutton Oil installation to Aberdeen. During the approach to Aberdeen airport the crew and passengers heard a loud bang followed immediately by the onset of severe vibration. The helicopter commander transmitted a PAN call and announced his intention of landing as soon as possible. Shortly before landing, control was lost and the helicopter struck the runway heavily on its right side. The airport fire and rescue services arrived at the accident site within one minute of impact. The aircraft, and its surroundings were sprayed with foam and the rescue personnel completed the release of the passengers. Ten of the sixteen passengers received serious injuries.

The report concludes that the accident resulted from the in-flight detachment of a hinge pin that secured the fairing which covered the final section of the tail rotor driveshaft. The fairing then opened and contacted the tail rotor, damaging all five blades. The resultant imbalance to the tail rotor assembly led to in-flight separation of this unit, and consequent loss of control. The report also concludes that poor flight safety communications on earlier incidents involving loss of hinge pin retention was a major contributory factor.

1. Factual Information

1.1 **History of the Flight**

The aircraft was on a return flight from the North-West Hutton Oil installation to Aberdeen Airport, with a crew of two pilots and sixteen passengers on board. The commander elected to make an Instrument Landing System (ILS) approach to runway 17 at Aberdeen Airport. During this approach, as the aircraft was descending through a height of approximately 200 feet above ground level, at an indicated airspeed of 100 knots, the passengers reported hearing a loud bang, and this was followed immediately by the onset of severe vibration which was apparent to the flight crew. There was no immediate deviation of the aircraft's flight path or attitude, however the commander suspected that there was a major problem with the tail rotor. At 1216.18 hrs he transmitted a 'PAN' call to Aberdeen Tower, reporting the vibration and stating his intention to land straight ahead on runway 17. Immediately on receipt of this message the controller ordered the airport fire services to come to 'LOCAL STANDBY'. The commander controlled the aircraft into a nose-up attitude in order to decelerate for a run-on landing at 40 knots. The aircraft continued towards the runway down to a height of about 50 feet above ground level, when, at an indicated airspeeed of 50 knots, it started to yaw to the left at a progressively faster rate, and finally became uncontrollable. The aircraft struck the runway heavily on the right main-wheel which, with its adjacent structure, was driven up through the cabin floor rupturing the fuel tanks in that area. The aircraft eventually came to rest on its right side, with the tail rotor and gearbox assembly detached, and the main rotor having disintegrated due to ground contact. The Airport fire and rescue service personnel arrived at the accident site within one minute of the impact. The aircraft, and its surroundings, were sprayed with foam and the rescue personnel then completed the release of the passengers.

1.2 **Injuries to persons**

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Serious	–	10	–
Minor/None	2	6	–

1.3 **Damage to Aircraft**

The helicopter sustained major damage and was beyond economic repair.

1.4 **Other Damage**

None.

1.5 **Personnel Information**

Commander:	Male, aged 39 years
Licence:	Airline Transport Pilot's Licence (Helicopters) valid until 22 June 1990.

Helicopter type ratings:	Westland S55 series 3 Wessex 60 series 1 Sikorsky S61N Aerospatiale AS 332L Tiger
Instrument Rating:	Initial issue on AS 332L 15 April 1983 valid until 15 May 1984
Medical Certificate:	Class 1 dated 27 January 1983 and valid until 31 July 1983
Certificate of test:	8 April 1983
Emergencies and Survival	
Equipment check:	15 April 1983
Flying experience:	Total all types: 5,855 hours
	Total AS 332L Tiger: 133 hours
	Total flying during previous 28 days: 53 hours
Duty time:	Off duty 2 July and 3 July
	On duty 0615 hrs until 12 18 hrs 4 July (6 hours and 3 minutes)
Co-pilot:	Male, aged 23 years
Licence:	Commercial Pilot's Licence (Helicopters) valid until 29 June 1992.
Helicopter type ratings:	Agusta-Westland Bell 47G series Aerospatiale AS 332L Super Puma/Tiger
Instrument rating:	None
Medical certificate:	Class 1 dated 24 August 1982 and valid until 31 August 1983
Certificate of test:	21 March 1983
Emergencies and Survival	
Equipment check:	24 September 1982

Flying experience:	Total all types: 1,063 hours Total AS 332L Tiger: 565 hours Total flying during previous 28 days: 67 hours
Duty time:	Off duty 2 July and 3 July On duty 0615 hrs 4 July until 1218 hrs 4 July (6 hours and 3 minutes)

1.6 Aircraft Information

1.6.1 General Information

Type:	Aerospatiale AS 332L
Constructor:	Societe Nationale Industrielle Aerospatiale, Marignane
Date of Manufacture:	July 1982
Constructors Serial No:	2026
Certificate of Registration:	G–TIGD/R1 Registered Owner: Bristow Helicopters Ltd.
Certificate of Airworthiness:	SR-1026–1 Transport Category (Passenger) valid to 11 July 1984
Certificate of Maintenance:	No. GD005, issued 1 July 1983 at 1,600 aircraft hours valid until 2 November 1983 or 2,040 aircraft hours
Aircraft Total Time:	1,607-30 hrs
Last Check:	Check 1 Phase 4 at 1,600 hrs
Next Check due:	25 hours
Engines:	Turbomeca Makila 1A

	Left Engine	Right Engine
Serial No:	121	320
Manufactured:	July 1980	March 1983
Engine Total Hours:	1,612	368-20
Engine Cycles:	564	112

1.6.2 *Maintenance Programme*

The basic Check 1 cycle, 400 hrs, is divided into four 100 hour phases to form a progressive maintenance plan. Superimposed upon the basic maintenance schedule are various out of phase items based on flying hours or calendar time.

The last maintenance check at 1,600 flying hours consisted of a Check 1 Phase 4 inspection together with all the inspections scheduled for this time with the exception of the 800 hr check which was deferred to 1680 hrs. The requisite dispensation being obtained.

These checks did not require any specific inspection or maintenance of the inclined driveshaft cowling or of its attachments. The last specific requirement for maintenance of the inclined drive fairing was at the Check 1 Phase 3 inspection performed on 8 June 1983 at 1,515-40 airframe hours. In addition to the scheduled airframe hours maintenance the aircraft was also subject to daily and pre-flight inspections. On none of these inspections is the inclined drive fairing specifically highlighted although on all inspections under 'Final Steps', the first item, is 'close cowlings and exits – correct working of locking devices.'

1.6.3 *Maintenance History*

In January 1983, the aircraft had suffered failure of a tail rotor blade pitch control horn, which resulted in very high vibration levels. As a result, a complete new tail boom assembly was fitted, modified to the latest standard which embodied the fitment of a steel inclined driveshaft fairing hinge assembly to replace the lower portion of the original all aluminium hinge.

1.6.4 *Tail Rotor*

The tail rotor of the Tiger is an articulated five bladed pusher type rotor, located on the right side of the tail pylon. The direction of rotation is anti-clockwise when viewed from the right side of the aircraft.

1.6.5 *Inclined Driveshaft Fairing (Refer Appendix 1)*

This fairing constitutes the leading edge of the tail pylon and is principally of glass reinforced plastic (GRP) honeycomb sandwich construction. Originally it was attached to the tail pylon by a single full length aluminium alloy hinge on the left side of the fairing and two overcentre type clasps (SARMA fasteners) on the right side. There was also a folding stay between the pylon decking and the fairing on the hinge side to prevent the fairing from opening too far during maintenance. The hinge pin is a steel rod with a shaped end installed from the lower end of the hinge and retained by springing the shaped end into a groove in a retaining button mounted on the fairing.

As a result of experience in service several modifications affecting the fairing attachment were raised.

(i) The SARMA fasteners were found to wear badly and, as a result, occasionally came open in flight. As a temporary expedient the operator developed an engineering practice of wire-locking the fasteners shut on the completion of any maintenance. As a more permanent remedy, the operator had proposed that an additional piano hinge fastening should be fitted on the right side of the fairing and pylon. This was designated BHL Mod 332-3306 and Issue 1 was CAA approved on 27 July 1982. This modification had not been applied to G-TIGD although the SARMA fasteners were wire-locked.

(ii) The hinge on the left side of the fairing was found to wear severely and as a result the manufacturer issued a modification AMS 07-21-539 which changed the forward half of the hinge components to steel. This modification had been applied to G-TIGD at the time that the tail boom was changed.

(iii) To improve the rigidity and location of the fairing on the pylon the manufacturer introduced two modifications, AMS 07-22-013 which called for two stiffening hoops to be bolted onto the inside of the fairing, one either side of the lower SARMA fastener position. Additionally a spigot fitting, attached behind the lower fastener, which engaged in a socket fitting attached to the tail pylon inclined decking was introduced by AMS 07-22-102. Both of these modifications were applied to G-TIGD at the time that the tail boom was changed.

(iv) The folding stay had to be disconnected or removed if the fairing itself was removed for maintenance. On one occasion this stay was removed and refitted to an aircraft the wrong way round and, as a result, damaged the tail rotor driveshaft.

The operator initiated modification action to delete the folding stay, but, in verbal consultation with the manufacturers local representative, understood that a modification AMS 20472 already existed to do this. However, some time after the accident the operator became aware that AMS 20472 referred only to the deletion of a spring attached to the folding stay and that this modification had been embodied at aircraft build. Upon realising that deletion of this stay was approved by neither the manufacturer, the French Airworthiness Authority, Direction General de l'Aviation Civile (DGAC) nor the British Airworthiness Authority, the Civil Aviation Authority (CAA), the operator re-installed the folding stay on all aircraft.

1.7 Meteorological information

The weather was not a factor in the accident. There was 1 okta of cloud at 3,500 feet, the visibility was good and the surface wind immediately before the accident was reported as 270°/13 knots.

1.8 Aids to navigation

The ILS to runway 17 at Aberdeen was serviceable and was being used by the aircraft at the time of the accident.

1.9 Communications

The aircraft had been in communication with Aberdeen from a range of 53 miles. At a range of 8.5 miles from touch-down, when established on the ILS, the aircraft changed to Aberdeen Tower on 118.1 MHz and thereafter remained on this frequency.

1.10 Aerodrome information – Aberdeen Airport

Aberdeen Airport is licensed for public use, and equipped with all the approach and landing aids normally associated with a major airport. On the day of the accident, the runway in use was 17. All the navigational, approach and radar aids were serviceable at the time of the accident flight.

1.11 Flight Recorders

The United Kingdom regulations did not require the helicopter to be fitted with any flight recorders, however, a Cockpit Voice Recorder was installed and a clear record was obtained.

1.12 Examination of Wreckage

1.12.1 Initial Examination (Refer Appendix 2)

The helicopter came to rest lying upon its right side at the south eastern corner of the intersection of runways 17 and 23 at Aberdeen Airport, the forward part of the fuselage being just on the grass along the edge of runway 17. The orientation of the fuselage was about 060° Magnetic.

The tail rotor complete with gearbox and the top of the tail pylon lay near the north western corner of the intersection approximately 50 metres away from the main wreckage. All five tail rotor blades were still attached to the rotor hub and all the pitch control mechanism was intact and undamaged at the hub end. All blades had complete leading edges but each had suffered varying degrees of damage which included loss of their composite trailing edge sections. Very few fragments of tail rotor blade were recovered at the main accident site and only one blade appeared to have suffered bending damage as a result of striking the runway. No marks were observed that would indicate that the tail rotor assembly had bounced or slid for any distance over the runway.

The main fuselage with tail boom and pylon up to the horizontal stabilizer was substantially intact, but the right undercarriage had been driven up into the fuselage underside, causing severe disruption of the cabin floor in the right rear quarter and giving rise to a considerable fuel spillage from the underfloor tanks. The main rotor blades had been almost totally shattered, all four being reduced to stumps about 1 metre long, still attached to the main rotor head, but all with their drag hinge stops broken. All doors and fairings were still attached to the aircraft with the exception of the main cabin entry door on the left side of the fuselage, and the inclined driveshaft fairing which normally constitutes the tail pylon leading edge. The cabin door was found, in fragments amongst the debris surrounding the main wreckage. The inclined driveshaft fairing, however, was found together with numerous fragments of tail rotor blades about 1 mile north of the accident site. The fairing was severely damaged, having had a large triangular section sliced off the upper right corner and a large section of outer skin from the lower left quarter was missing. The detached portions included the end portion of the hinge and the hinge pin retention button. The hinge pin itself was not recovered despite a most thorough search being made.

1.12.2 *Detailed Examinations*

1.12.2.1 *Structure – General (Refer Appendix 3)*

Examination of the fuselage structure revealed evidence of a heavy ground impact on the right side of the passenger cabin. The flattened area extended from the rear edge of the pilots door to the tapering section of fuselage behind the main undercarriage. The plane of the crushing damage was at about 70° to the horizontal, and the fuselage section had assumed a trapezoidal shape with the roof deflected to the right relative to the cabin floor. The right main undercarriage had been driven into the passenger cabin by the impact, and had totally disrupted the underfloor structure and forced up the cabin floor in the area of the undercarriage attachment. The disturbance of the structure had also caused three bag type fuel tanks, under the cabin floor to rupture. The ruptured tanks were the two aft tanks and the right collector tank below the cabin door frame on the right side of the fuselage.

There was evidence of ground impact damage on the right side of the tail pylon and some compressive buckling of the tail boom skin on the left side at the tail boom/pylon intersection. The tail pylon had been detached at the lower tail rotor gearbox mountings and the upper surface of the horizontal stabilizer had been pierced in three places.

There was no evidence of the main rotor blades having struck any part of the helicopter structure.

1.12.1.2 *Transmission*

The transmission was checked in situ, and all driveshafts and free wheels were found to operate smoothly and correctly. Although the main rotor had struck the ground with sufficient force and energy to destroy the blades completely and disrupt the drag hinges, the main rotor head was still attached to its mountings. The tail rotor driveshaft was complete through the angled intermediate gearbox to the attachment of the tail rotor gearbox flexible coupling. The flexible couplings on both sides of the intermediate gearbox (IGB) showed evidence of considerable angular displacement whilst the shaft was rotating and the rear IGB mounting had fractured, the fracture faces being severely hammered by post failure movement.

The tail rotor gearbox/inclined driveshaft flexible coupling had failed as a result of combined bending and torsion, the coupling itself showing evidence of severe angular displacement whilst rotating.

1.12.1.3 *Main and Tail Rotor Controls*

Although all main rotor blades had been forced past their drag hinge stops, only one of the pitch control rods had failed and that as a result of a tensile overload.

The tail rotor control rod between the quadrant on the tail pylon and the tail rotor control servo had failed in bending overload in the region of the gearbox separation at the top of the pylon. The feedback linkage on the servo itself had been disrupted during the ground impact.

Examination of the control systems showed that distortion of fuselage had given rise to restrictions of some control runs and slackening of layshaft bearings giving rise to free-play. After easing the restrictions and making allowances for the free-play, comparison of movements with those on an airworthy aircraft were reasonable.

Rig checks on all main rotor primary servos and the autopilot servo pack showed them to be fully serviceable. It was not possible to check the tail rotor servo due to the impact damage, however, it was established that the ram was still free to move and that all the blade pitch change linkages still operated correctly.

1.12.1.4 *Engines*

The engines were found securely attached to their mountings. Visual examination revealed no signs of internal damage or distress and both free turbine output driveshafts were intact, connected to the main gearbox, and with the free wheel units functioning correctly.

The rigging of the controls to both engines was checked and found to be satisfactory.

1.12.1.5 *Tail Pylon Inclined Driveshaft Fairing and Tail Rotor*

Examination of the tail rotor in conjunction with the pylon and fairing revealed that four of the five tail rotor blade leading edges had paired hemispherical dents, the separation of which matched that of the paired dome headed screw on the fairing which attached the two re-inforcing hoops (Refer Appendix 4). The fairing itself showed damage consistent with being struck several glancing blows by the tail rotor whilst in an open position with the two SARMA fasteners on the right side acting as hinges. The fifth tail rotor blade had a clear imprint of a SARMA fastener in its leading edge in a position consistent with the fastener being engaged on its latch on the pylon but with the fairing open towards the tail rotor. There were also witness marks on the blade and on the side of the pylon structure consistent with the blade having struck a glancing blow on the right side of the pylon. A large triangular section from the right aft corner of the fairing had been severed by the tail rotor blade. To achieve this the blade had flapped towards the pylon more than the flapping stops permitted. Examination of the tail rotor blade flapping stops revealed that all blades had exceeded their flapping limits in both senses during the accident sequence.

Examination of the left side of the tail boom in the area around the forwards extension of the fairing hinge line revealed a number of scores on the surface paint and across rivet heads. The scores were in the form of arcs centred approximately at the lower end of the hinge. The arc score furthest from the hinge was at a distance which equated to its being made by the tip of the hinge pin shaped end when only 1½ inches of the pin was engaged in the hinge. This area of skin was examined on all other aircraft in the operator's fleet and the marks were established as being unique to the accident aircraft.

The bottom lug of the hinge portion attached to the tail boom had failed, the hinge pin having burst through it in an upwards direction. The bore diameter and ovality of all the hinge lugs recovered were measured and compared with those of a new hinge. The mean size of bore in a new hinge lug was measured as 0.136 inches. The bores in the accident aircraft's hinge ranged from 0.180 inches at the lower end to 0.136 at the top with almost consistent ovality of 0.010 inches above measured diameter. The hinge pin was not recovered and consequently the wear pattern on it could not be established. However, some hinge pins subsequently removed from other aircraft of the fleet showed marked wear stepping, particularly towards the lower end. (Refer Appendix 5).

Examination of the failed upper pylon where the tail rotor gearbox assembly had separated from the helicopter showed that the general direction of departure was to the left with a torsional element centred near the pylon rear spar. A metallurgical examination of this structural fracture was made. This revealed no evidence of long term fatigue in the various fractures. There were, however, indications of rapid high strain fatigue in the starboard side skin.

1.13 Medical and Pathological Information

Not relevant.

1.14 Fire

There was no fire.

1.15 Survival aspects

In spite of the severity of the impact and resultant damage to the interior of the cabin, all the occupants survived the accident, although 10 passengers sustained serious injuries. As the aircraft struck the ground heavily on its right side, the right main landing gear assembly was forced up into the fuselage, piercing the right side under-floor fuel tanks, and grossly distorting the aft seat retaining rails. As a result the fourth and fifth double passenger seats on the right side were detached from the retaining rails and pushed upwards towards the cabin roof. When the fuel tanks ruptured, about 185 kg (408 lbs) of fuel was released; a proportion entering the passenger cabin, with the major quantity spilling onto the ground beneath and around the right side of the aircraft.

Immediately after the helicopter commander transmitted the PAN message (1216.18 hrs) the Aberdeen Air Traffic Local Controller alerted the Fire and Rescue personnel to 'LOCAL STANDBY'. At the moment of impact

(1217 hrs) the Omni-Directional Crash Alarm System was activated, and the response was immediate. Within 1 minute of the impact the first three appliances, comprising one Rapid Intervention Vehicle, one Javelin Foam Tender, and one Nubian Major 1500 Foam Tender arrived at the accident site. By this time the two flight crew members were at the left side main door assisting in the evacuation of the passengers. The fuel spillage was observed and 300 litres of Fluorochemical Foam (AFFF) was discharged to cover the fuel and to cool the hot parts of the aircraft fuselage. Once the danger of fire had been minimised the rescue of the remaining passengers, two of whom were unconscious, was completed by the Fire Service personnel. Some difficulty was experienced in releasing the last two casualties from the aircraft due to the position of the detached seats and retaining rails. Shortly after the removal of the last casualty from the aircraft, units from the Grampian Fire Brigade, Grampian Police, and Scottish Ambulance Service arrived at the scene. A company helicopter transferred the two unconscious casualties to the Aberdeen Royal Infirmary, the other 16 casualties being transferred by ambulance.

1.16 Tests and Research

None.

1.17 Additional Information

1.17.1 Royal Air Force experience with the Aerospatiale AS 330 Puma

The AS 330, Puma, entered service with the RAF in 1971. As a result of incidents involving the disengagement of a fairing hinge pin from the retainer and a fracture at its shaped end, the RAF introduced a modification (Command Modification/Puma/051) in July 1973 to prevent migration of the hinge pin. This modification was revised in 1977 (SEM/PUMA/034) to take into account other modifications in this area.

Westland Helicopters, as manufacturer of the RAF Puma and the holders of a limited design authority in respect of modifications to the RAF fleet, were informed of this modification as a matter of routine. They were not requested, and their design authority did not require them to take further action. As a result neither Aerospatiale, DGAC nor the CAA were informed of this modification. In addition, at that time, there was no formal exchange of safety information between the Ministry of Defence and the UK Civil Aviation Authority.

1.17.2 Bristow Helicopters experience with Aerospatiale AS 330 Puma

The Puma type entered service with Bristow Helicopters in July 1977. On 7 June 1979 Puma G–BERG suffered the loss of the inclined driveshaft (IDS) fairing hinge pin whilst in flight. The folding stay (Refer Appendix 1) was fitted to this aircraft and this appears to have restricted the opening of the fairing, so preventing interference between the tail rotor and the fairing. As a result, Bristows raised a modification (BHL/Puma/1038) which introduced a 'P'-clip to retain the shaped end of the hinge pin and prevent migration of the pin. No Mandatory Occurrence Report (MOR) was sent to the Civil Aviation Authority (CAA) in respect of this incident, nor was the manufacturer, Aerospatiale, made aware of the modification.

An informal exchange of safety information existed between Bristow Helicopters and the Royal Air Force with regard to Puma operations. Despite this liaison the two operators fitted fundamentally different modifications to prevent the inclined driveshaft fairing hinge pin from migrating out of engagement. The RAF modification consisted of a blocking device to limit pin migration in the event of the shaped end of the pin either fracturing or becoming disengaged from its retaining button. The Bristow Helicopters modification consisted of a 'P' clip providing secondary security to the shaped end of the hinge pin but this modification was not designed to prevent migration of the hinge pin in the event of a fracture of its shaped end. (Refer Appendix 6).

The responsibility for the promulgation of safety information and advice to civil Puma operators rested with the manufacturer Aerospatiale. Such information is endorsed by the French Airworthiness Authority (DGAC) who then pass on this information to national airworthiness bodies including the UK Civil Aviation Authority. This safety information is based on information received by the manufacturer from operators, both civil and military, throughout the world.

Since the Puma entered service a number of accidents and incidents had been attributed to fairings and hatches opening in flight (Refer Appendix 7). Both military and civil operators had expressed concern about the flight safety hazards associated with these events.

1.17.3 Bristow Helicopters Experience with the Aerospatiale AS 332L Tiger

Before taking delivery of the Tiger aircraft, Bristow Helicopters reviewed the applicability of their Puma modifications to the new type with the manufacturer, Aerospatiale. On the specific topic of the IDS fairing hinge pin retention, misinterpretation of the description 'reversal of hinge pin retention' (in fact indicating that the shaped end was now retained by a button attached to the fairing itself rather than one on the fixed pylon structure) led the operator to believe that their Puma modification was inappropriate.

The UK validation of a civil aircraft design covered by a foreign 'Type Certificate' does not specifically review military experience on similar types. The CAA consider that this is the primary responsibility of the Airworthiness Authority from the state of manufacture, in this case DGAC. Consequently at the time of UK validation of the AS 332L (Tiger) the RAF hinge pin retention modification was not considered and the potential hazard associated with hinge pin migration was not recognised. Furthermore, the CAA were not aware of the full history of insecure hatches and fairings on the Puma type experienced by the military and civil operators.

Since its introduction into service the AS 332L Tiger, like its predecessor the AS 330 Puma, had caused concern to the operator due to the insecurity of hatches, fairings and openable cowlings. The operator had informed the manufacturers of this concern.

1.17.4 *Fracture of hinge pin on G–TIGK on 7 July 1983*

Three days after the accident to G–TIGD, another aircraft of the operator's fleet (G–TIGK) was found to have a fractured inclined driveshaft fairing hinge pin. The failure had occurred at the bend forming the start of the shaped end of the hinge pin. The pin had not, however, migrated from its proper position and the shaped end had been retained by a clip fitted after the accident to G–TIGD. Both portions of the broken pin were returned to the manufacturer where metallurgical examination showed that the pin had fractured as a result of a fatigue mechanism.

1.17.5 *AS 332L Optional Crashworthy Installations*

The helicopter manufacturer offered as optional equipment, a crashworthy installation consisting of a modified cabin floor, modified crew seating and a crashworthy fuel system.

The following is an extract from the manufacturer's optional Equipment Type Specification for the crashworthy fuel system:

> "The 5 tanks comprise a flexible wall consisting of a highly resistant cloth coated with elastomer, certified for drop speeds of up to 14 metres per second and capable of withstanding instantaneous high pressure due to a crash and resistant to perforation, tearing or stripping off due to aircraft structure damage. Connections are designed to resist crash distortion. All pipes are flexible and the equipment supports (pumps ejectors etc) are weakened to detach themselves from the structure and remain an integral part of the tank."

The crashworthy fuel system installation carries penalties in terms of cost, weight and range. Of the three UK companies operating the AS 332L, none have opted for the crashworthy installation.

2. Analysis

2.1 The Loss of Directional Control

Analysis of the area of primary impact on the right side of the fuselage shows that the aircraft struck the ground with a high rate of descent, banked at 70 degrees in a slightly tail down attitude. Had the tail rotor, which projects from the right side of the tail boom, been attached at the initial impact, the pitch change mechanism would have suffered a heavy contact with the runway, and there would have been evidence of a scuffing contact of the outer faces of the tail rotor blades on the runway. Since none of these features were observed on the tail rotor, which was found lying some distance from the main wreckage, it is apparent that the top of the pylon, together with the tail rotor and gearbox, must have detached shortly before the aircraft struck the ground. Loss of the tail rotor in powered flight would lead to immediate loss of directional control, and this was undoubtedly experienced on this aircraft very shortly before the crash.

The examination of the tail pylon fracture showed no evidence of long term fatigue damage but did exhibit some evidence of rapid high strain fatigue, indicative of severe oscillatory loading over a short time. Historically such failures of helicopter tail pylons have been associated with tail rotor damage and consequent severe vibration. In this case the crew reported the sudden onset of severe vibration following a loud bang after the aircraft had passed the middle marker about 1¼ miles from the crash site.

Parts of tail rotor blades and the inclined driveshaft fairing from the tail pylon were located about 1 mile back track from the accident site. Examination of the tail rotor and fairing indicated that the rotor blades had been damaged by striking the fairing which had subsequently become detached. The nature of the damage to the fairing indicated that it had hinged about its two SARMA fasteners and been struck by the tail rotor, and this in turn required that the location provided by the hinge on the port side of the fairing had released in some manner.

The arc shaped scores on the paintwork on the port side of the tail boom indicated that the fairing hinge pin had migrated slowly out of engagement within the hinge with the free portion flapping beside the tail boom. Migration of the hinge pin is only possible if the retention of the shaped end disengages from the retention button on the fairing or the shaped end of the pin fractures. The tendency for the hinge pin to migrate would be encouraged by gravity and vibration and made easier by wear in the hinge lug bores. The intermittency of the arc scores can be explained by postulating that the hinge pin rotated as it migrated and scoring only occurred with the pin positioned in a limited rotary arc with the shaped end pointing towards the fuselage. This supposition leads to the conclusion that the shaped end of the hinge pin was intact and its cut off end was only part of the rod capable of scoring the paint. Alternatively the shaped end of the hinge pin may have broken off when in engagement with the retaining button and the intermittency of the arc scores was the result of the changing vibration characteristics of the pin as it migrated out of the hinge.

Since neither the hinge pin nor the retaining button was recovered it is not possible to determine which of the two alternatives prevailed. It should be noted that there has been at least one recorded instance of the hinge pins shaped end fracturing thereby releasing hinge pin retention.

In a previous incident involving loss of a hinge pin in flight (on the almost identical arrangement on a Puma helicopter) the inclined driveshaft fairing only partially opened and did not interfere with the tail rotor. The most significant difference appears to be that the folding stay on the hinge side of the fairing was fitted to the Puma and prevented the fairing striking the tail rotor. The folding stay had been removed from G–TIGD by an operators engineering instruction. It was unfortunate that the significance of the folding stay in preventing the IDS fairing striking the tail rotor on the earlier Puma occurrence was not appreciated at that time. However, the folding stay was a component designed to be used only during servicing and was not therefore considered to affect the in-flight retention of the fairing.

The high replacement rate of SARMA fasteners on the inclined driveshaft fairing, together with the severe wear observed in the early aluminium fairing hinges are indicative of an inherently high vibration level in this zone of the aircraft. This in turn would tend to encourage migration of the hinge pin should it become unlatched and furthermore would increase the chance of the shaped end of the hinge pin becoming unlatched if it were not fully engaged on its retaining button. The wear pattern observed on the hinge of G–TIGD (increasing towards the lower end) would lead one to suppose that, once free, the hinge pin would have a rapidly increasing ease of migration the further it had progressed.

In view of the history of fairing and hatch insecurity on Tiger and Puma helicopters it would seem prudent that the manufacturer and airworthiness authorities review the methods of attachment in order that further instances of inadvertent opening or detachment in-flight are prevented.

2.2 Airworthiness Communications

The generically similar AS 330 Puma type had been in service for 12 years with the RAF and 6 years with Bristow Helicopters at the time of the accident to G–TIGD. Both the AS 330 and AS 332 types had also been in service with other operators.

Confining consideration to the tail pylon area, it would appear that operators, whilst fully aware of their own problems, had not been formally advised of those of other operators. Safety information and advice to civil operators would normally be expected to be promulgated by the French manufacturer Aerospatiale, endorsed by the national airworthiness authority (DGAC) who would then inform the UK Civil Aviation Authority. The Royal Air Force airworthiness experience was communicated to Westland Helicopters who had limited design authority for the RAF Puma fleet but who were only required to inform Aerospatiale of RAF modifications when specifically requested to do so by the Ministry of Defence. Aerospatiale, therefore, did not necessarily have the fullest information on which to base advice to civil operators. As a result there seems to have been little or no exchange of information on many of the problems encountered in service between the civil and military fleets.

Whilst it is appreciated that communication of all matters, however small, between all interested parties would create difficulties, it is clear that the potential hazards associated with the loss of hatches and fairings in flight, particularly on helicopters, cannot be overstated. In the particular case of the insecurity of the inclined driveshaft fairing, none of the interested organisations appear to have had sufficient information of the overall frequency of the problem to attach the required urgency to produce a comprehensive and timely solution to it.

The root cause of this accident, ie failure of the hinge pin retention is fundamentally straightforward, requiring minimal design and embodiment effort to effect a solution. All concerned appear to have failed to appreciate the potential hazards arising from the problem due to its very simplicity.

If accidents of this type are to be avoided in the future then communication on flight safety matters between the operators, manufacturers and airworthiness authorities must be dramatically improved. Operators should be reminded of their obligation to report all occurrences that affect flight safety and of the necessity to inform the manufacturer and the airworthiness authorities of any modification arising from these occurrences, irrespective of size or cost of the modification. Additionally, the airworthiness authorities should seriously consider extending the formal occurrence reporting system to embrace both civil and military experience where common aircraft types are operated.

2.3 Survival Aspects

The examination of the wreckage revealed that the impact forces had ruptured the underfloor fuel tanks on the right side of the helicopter. A considerable quantity of fuel was released both into the passenger cabin and onto the ground beneath the helicopter and it was very fortunate that this fuel did not ignite and result in far more serious consequences.

The AS 332L (Tiger) complied with the requirements of BCAR Chapter G5–2 which required the fuel tanks to retain fuel under certain specified crash landing accelerations. In this case the fact that the impact was sufficiently violent to rupture the fuel tanks suggests that the impact was more severe than that covered by the BCAR. However, that all occupants survived in a relatively intact passenger cabin demonstrates that the accident was physically survivable but that this survival was put at risk by the potential fire hazard resulting from the fuel spillages. Therefore it is clear that a realistic improvement in crash survivability could be achieved by requiring improved protection for fuel tanks and fuel systems.

Aerospatiale in line with other major helicopter manufacturers offer an improved 'crashworthy' fuel system as an option to operators ordering the AS 332L Tiger. The installation of this system, which includes a puncture resistant tank material, may well have prevented the release of fuel experienced in this accident and would have significantly reduced the risk of death or injury through any post-impact fire.

There is at present, no requirement for these safety features to be fitted to helicopters and until the Airworthiness Requirements are amended to make such features mandatory, few, if any operators will take up the manufacturers option. It would be naive to assume that operators voluntarily opt for these features, when, in doing so, they place themselves at a commercial disadvantage with respect to competitors, in having to bear the additional cost and weight penalties involved with such installations.

3. Conclusions

(a) *Findings*

(i) The crew were properly licenced and adequately experienced to conduct the flight.

(ii) The helicopter had been maintained in accordance with an approved maintenance schedule and the Certificates of Maintenance and Airworthiness were valid at the time of the accident.

(iii) A complete loss of directional control was encountered at a late stage of the approach to land at Aberdeen Airport.

(iv) The inclined driveshaft fairing opened in flight due to the disengagement of the inclined driveshaft fairing hinge pin.

(v) The method employed to retain the fairing hinge pin was not sufficiently positive.

(vi) The absence of the fairing folding stay removed by an Operators engineering instruction (a modification not approved by the manufacturer or the airworthiness authorities) allowed the fairing to open sufficiently to interfere with the tail rotor.

(vii) After opening, the inclined driveshaft fairing was struck by the tail rotor blades, all of which suffered loss of parts of their trailing sections.

(viii) The mechanical damage to the tail rotor resulted in an inertial and aerodynamic imbalance which caused severe airframe vibration.

(ix) The tail rotor complete with its gearbox and the upper portion of the tail pylon, separated from the aircraft as a result of the severe airframe vibration.

(x) A modification providing secondary retention of the hinge pin, incorporated on Puma helicopters belonging to the same operator following the loss of an inclined driveshaft fairing hinge pin had not been incorporated into the design of the Tiger despite similarities in the design of the area on both helicopter types.

(xi) Information regarding the Royal Air Force incidents involving fairing hinge pin retention and the subsequent service modification resulting from them, although communicated to the UK manufacturer by the RAF, was not subsequently passed on to the French manufacturer nor to the Civil airworthiness authorities.

(xii) The communication of airworthiness information between the operators, manufacturer and airworthiness bodies was inadequate and resulted in a lack of appreciation of the scale of the problem by all concerned.

(b) *Cause*

The cause of the accident was the loss of directional control following the detachment in flight of the tail rotor assembly. The accident sequence was initiated by the disengagement of a driveshaft fairing hinge pin which allowed the fairing to open and contact the tail rotor, damaging the blades. This in turn led to a rotor imbalance, severe airframe vibration and a structural failure of the tail pylon at the tail rotor attachment.

A major contributory factor was poor flight safety communication on earlier incidents involving loss of hinge pin retention.

4. Safety Recommendations

It is recommended that:

4.1 The manufacturer and French airworthiness authority should review the methods of retention of opening cowlings, fairings and panels on the AS 332 Tiger and generically similar types.

4.2 The UK Civil Aviation Authority should consider expanding the existing occurrence reporting systems to embrace both military and civil experience.

4.3 The UK and French airworthiness authorities should formulate improved crashworthiness design criteria for helicopter fuel systems for incorporation in the Civil Airworthiness Requirements.

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