



**Australian Government**

**Australian Transport Safety Bureau**

**ATSB TRANSPORT SAFETY INVESTIGATION REPORT**

Aviation Occurrence Report – BO200502316

Final

# **In-Flight Failure of a Tailrotor Drive Shaft**

**Fig Tree Pocket, Qld**

**13 May 2005**





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### Abstract

On 13 May 2005, a McDonnell Douglas Hughes 369E helicopter, registered VH-INM, experienced an in-flight failure of the tailrotor drive shaft. The aircraft had departed Archerfield Airport, Qld, and was in climb to cruise at approximately 1,000 ft above ground level when the pilot encountered tailrotor control difficulties. The aircraft was landed and brought to rest in an upright position at Fig Tree Pocket, Qld.

The broken tail shaft (P/N 369D21615-41) was submitted to the ATSB, where examination revealed that the component had sustained a twisting buckling failure from excessive torsional loads. The investigation did not reveal any evidence of pre-existing damage that might have initiated the failure.

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# THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau is pleased to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

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# 1

## FACTUAL INFORMATION

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### 1.1 History of the flight

On 13 May 2005 at 1030 Eastern Standard Time, a McDonnell Douglas Hughes 369E helicopter, registered VH-INM, experienced an in-flight failure of the tailrotor drive shaft.

On the day of the occurrence the helicopter had been performing aerial survey work for approximately 1.7 hours under visual flight rules (VFR). After refuelling and on departure from Archerfield Airport, the aircraft was in climb to cruise at approximately 1,000 ft AGL when flight control difficulties were encountered.

The pilot in command (PIC), the sole occupant, reported that he heard a loud bang and felt a shudder through the tailrotor pedals. The PIC suspected a tailrotor failure so he lowered the collective and tracked the aircraft for a nearby paddock. The aircraft was positioned for a run-on landing at about 50 to 60 kts whereby it was brought to rest in an upright position. The PIC was not injured.

### 1.2 Damage to the aircraft

Inspection of the MD369E at the operator's maintenance facility revealed that the aircraft sustained complete failure and separation of the tailrotor drive shaft. Abrasion damage to the interior tailboom skin and support structure was also found. In addition, the inspection revealed that the inboard teeter hinge bolt from the tailboom section was slightly bent.

It was reported by the maintainer that subsequent inspection of the MD369E indicated that the tail and main gearboxes were in serviceable condition. No obvious damage to the tail or main rotor system was found.

The broken tail shaft was submitted to the ATSB with the view to determine the mode and causal factors that contributed to the component failure.

### 1.3 Aircraft information

#### 1.3.1 Tailrotor drive shaft

The MD369E helicopter S/N 0457E was powered by a single Allison 250-C20B gas turbine engine. The helicopter was equipped with a single five-blade main rotor that provided lifting force and a four-bladed tailrotor that provided anti-torque and directional control. The tailrotor drive shaft and tailrotor transmission were housed within the tailboom of the aircraft which acted as the supporting structure for the vertical and horizontal stabilisers.

The tailrotor drive shaft connected the main transmission and the tailrotor transmission, which provided torsional power to the anti-torque system. The failed drive shaft was a hollow cylindrical section approximately 3.96 m in length with a wall thickness of 1.20 mm and an outer diameter of 70 mm. The shaft tapered at each end and flanges were used to attach the shaft to the flexible joint couplings. To



minimise vibration and lateral flex during service, a damper was fitted to the centre of the shaft. An illustration of the tail shaft from a MD369E is shown in figure 1.

**Figure 1: Location of the tailrotor drive shaft (shaded) onboard the MD369E. The position shaft damper is also highlighted.**

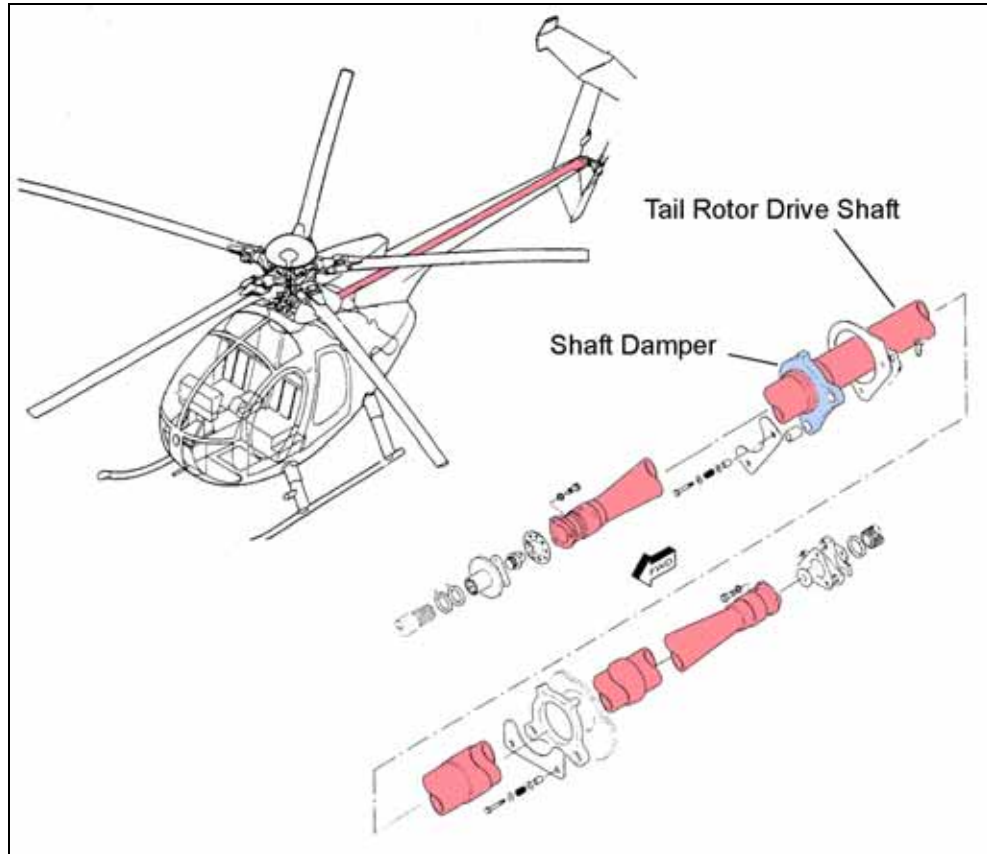


Image Reference: MD Helicopters Inc. Illustrated Parts Catalogue (CSP-IPC-4), Revision 10 19 November 2004.

## 1.4 Service history and maintenance

The helicopter was operated in the United States until July 2003. After that date, the aircraft was imported to Australia with a total time in service (TTIS) of 19,339.5 hours. The aircraft had accumulated an additional 334.9 service hours until the in-flight occurrence at 19,674.4 hours TTIS.

The tailrotor drive shaft, P/N 369D25518-501 S/N 009999-3892, had been installed on the aircraft as a new component. The shaft had performed a reported 5,774.4 hours of flight service prior to the failure event.

### ***Continued airworthiness***

The MD369E tailrotor drive shaft was specified as a 'life-limited' component to which a limited number of hours or flight cycles are assigned. The airworthiness limitations schedule for the tail shaft on the MD369E was restricted to a finite life

of 13,900 hours<sup>1</sup>. Continued airworthiness was also maintained by completing an inspection every 100 hours and 300 hours of flight service. A yearly inspection was also required.

These time-based schedules called for the drive shaft to be inspected for evidence of various types of damage including; buckling, dents, scratches and any other sort of obvious damage. At these times, a drive shaft twist inspection was also required to examine for twisting deformation due to an over-torque event.

### ***Repair limitations***

The manufacturer had placed damage tolerance limitation for the tailrotor drive shaft that extends to nicks, scratches and smoothly contoured dents<sup>2</sup>. The shaft was deemed unserviceable and should have been replaced if any damage was found outside the specified limits shown in table 1.

**Table 1: Damage tolerance limits for the tail shaft.**

<b>Damage Type</b>	<b>Max Depth</b>	<b>Max Length</b>
Random Scratch	0.007 in (0.178 mm)	1.00 in (25.40 mm)
Random Scratch	0.010 in (0.254 mm)	0.254 in (6.35 mm)
Circumferential Scratch	0.004 in (0.102 mm)	
Dent	0.040 in (1.016 mm)	

## **1.5 History of related tail shaft failures**

As part of this investigation, the Australian Civil Aviation Safety Authority and U.S Federal Aviation Administration service difficulty reports were searched for the period 1994 to 2005. No records of similar tail shaft failure events were found. In addition, a search of the U.S. National Transportation Safety Board, Transportation Safety Bureau of Canada and the ATSB occurrence databases revealed no failures of this nature.

A United Kingdom Civil Aviation Association paper<sup>3</sup> on tailrotor failures was also reviewed as part of this investigation. The study pointed out that the known conditions that could contribute toward tailrotor drive shaft failures were normally encountered when the tailrotor system struck an object, for example; ground, vegetation or a bird, or when a gross mechanical failure of the tailrotor system occurred during operation.

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<sup>1</sup> MD Helicopter Inc. Maintenance Manual CSP-HMI-2, Section 04-00-00, Page 9.

<sup>2</sup> MD Helicopters Inc. Maintenance Manual CSP-HMI-2, Section 63-15-10, Page 801.

<sup>3</sup> UK Civil Aviation Authority, Paper 2003/1, Helicopter Tail Rotor Failures, Issued November 2003, Section 2 Page 14.

## 1.6 Physical examination

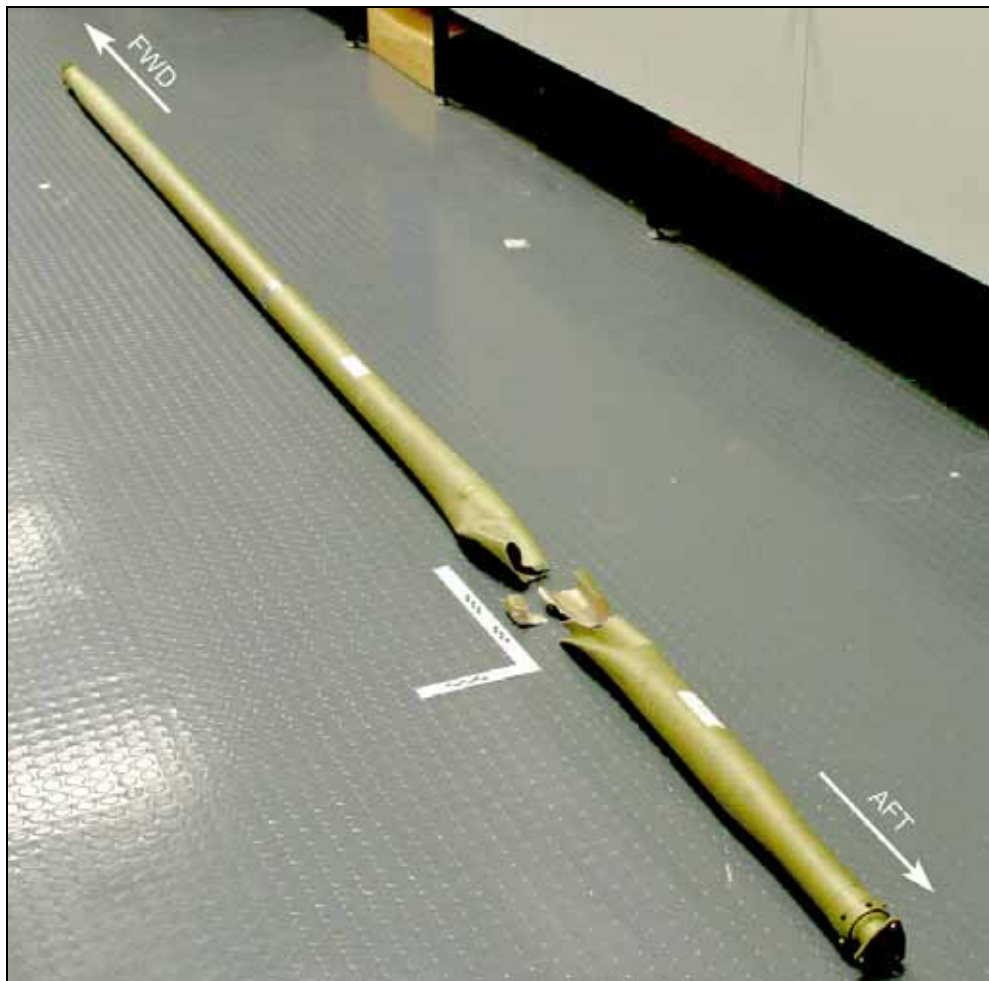
### 1.6.1 Method of examination

The fractured region from the tailrotor drive shaft was examined optically using a binocular microscope and at higher magnification using the scanning electron microscope (SEM). Material characterisation including metallography, hardness, conductivity and semi-quantitative chemical analysis was also performed on the broken component.

### 1.6.2 Visual examination

Initial examination of the tailrotor shaft, as-received by the ATSB, revealed that the component had fractured through the rear section approximately 760 mm from the tailrotor gearbox connection. The failure had caused the shaft to separate into four pieces with two of them being main tubular sections and the other two being much smaller fragments, see figure 2.

**Figure 2: Photograph of the broken tailrotor drive shaft (P/N 369D25518-501, S/N 009999-3892) as-received by the ATSB.**



One of the main features observed on both shaft segments was the significant degree of twisting-type distortion. When both shaft segments were aligned to the pre-failure position, as shown in figure 3, the corruption to the component structure became evident. The general shape of the damage indicated that failure had occurred by buckling and was driven by torsional loading. The indicated direction of torsion, as viewed looking aft, was as if the forward portion of the shaft rotated clockwise relative to the aft portion of the shaft, see figure 4.

Secondary damage to the shaft included many randomly oriented scratches and scores to the painted surface and underlying substrate, see figure 5. Several deeper circumferential scratches and indentations were noted on the most severely folded sections of each shaft fragment. The general appearance of this damage was consistent with contact with the tailboom inner fairing after the primary shaft failure.

The smaller fragments of the drive shaft were examined and showed similar damage patterns with a significant level of deformation and bending present. The general appearance of this damage indicated that at some point during the failure event both fragments had become liberated from one of the main sections of broken shaft.

**Figure 3: View of the failure location.**



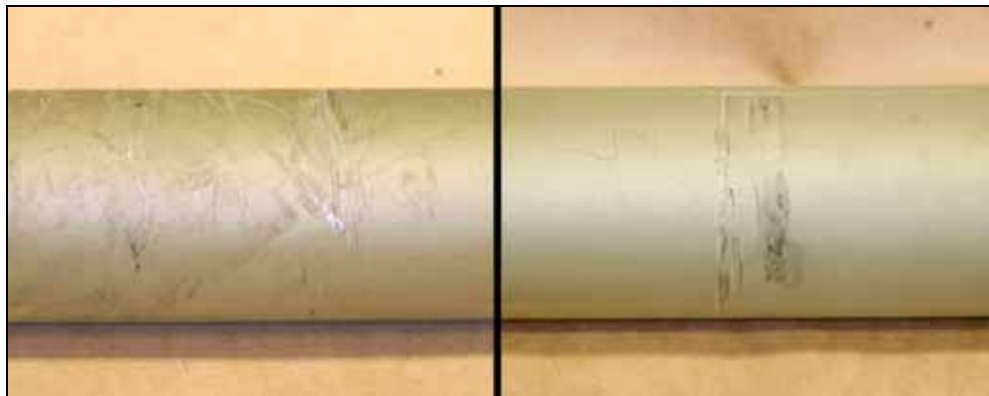
A label with manufacturing identifiers, Part Number 369D25518-501 and Serial Number 009999-3892, was observed on the forward end of the component.

A sleeve had been installed around the middle of the shaft as part of the shaft damper mechanism. Some minor blemishes were observed on the sleeve surfaces.

**Figure 4:** Close view of the buckling to the shaft structure. The torque reaction required to produce such deformation is arrowed.



**Figure 5:** Various external secondary surface damage including scratches, rotational scuff marks and indentations were observed along the length of the shaft.



### **1.6.3 Fracture surface examination**

Under low power magnification, the fracture surfaces showed mainly clean fractures on either a 45- or 90-degree plane inclined to the shaft axis. Such features are typical of tearing or shear type-failures in ductile materials. Some fracture surfaces showed significant mechanical damage where the finer fracture details had been obscured. In these areas the damage was consistent with having been produced during the mechanism of fracture as the shaft failed.

No evidence of pre-existing defects, fatigue crack growth, or other such features that could have contributed to the failure were observed. Nor was any evidence of corrosion or any other form of environmental degradation found where the internal or external surface protection schemes had been compromised.

### **1.6.4 Scanning electron microscopy**

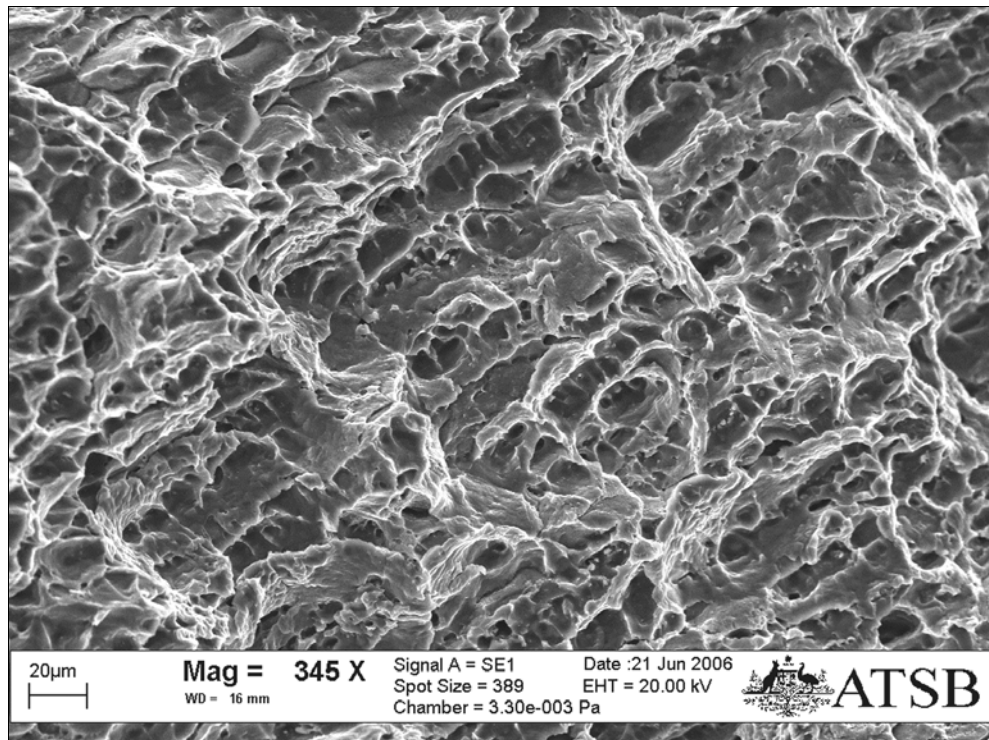
All of the fracture surfaces from the broken drive shaft were examined in detail at high magnification using the scanning electron microscope (SEM). The

examination revealed only evidence of ductile tearing or shearing from a gross overload event, see figure 6.

Some of the fracture surfaces had their finer features obscured from ‘metal-to-metal’ contact, see figure 7. The general appearance of the contact marks indicates that the damage had been caused subsequent to the shaft failure.

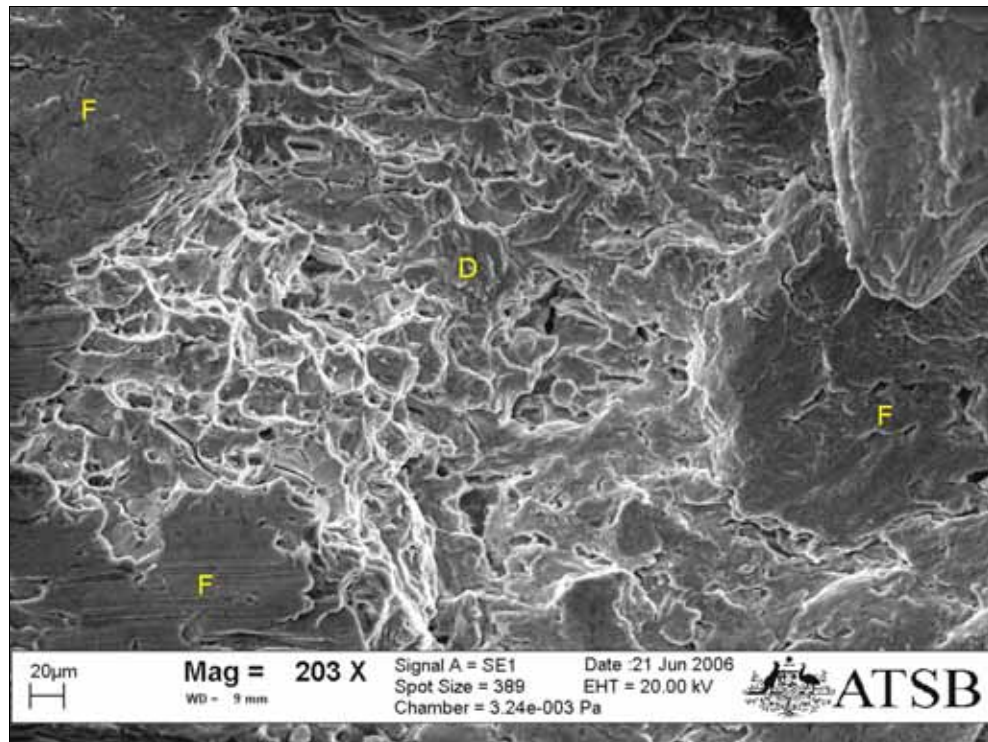
No evidence of crack progression or striations that might suggest fatigue cracks had been present in the component prior to the failure event was observed.

**Figure 6: High magnification scanning electron micrograph of the fracture showing a typical region of ductile overload.**





**Figure 7:** Scanning electron micrograph of the fracture surface showing ductile overload areas, labelled 'D', and some regions of post-failure damage, labelled 'F'.



### **1.6.5 Chemical analysis**

Semi-quantitative chemical analysis of the tailrotor drive shaft material was made using the energy dispersive x-ray (EDS) detector on the SEM. The analysis revealed the drive shaft material to be comprised mainly of aluminium with a minor alloy addition of magnesium. Such a composition is indicative that the shaft was made from either a 5XXX or 6XXX series aluminium alloy.

### **1.6.6 Conductivity**

In order to further categorise the material type comprising the tailrotor drive shaft, conductivity measurements were performed. An average conductivity of 44.1 %IACS<sup>4</sup> was measured, which was consistent with either a 5XXX or 6XXX series wrought aluminium alloy.

### **1.6.7 Hardness**

Hardness measurements on the alloy comprising the tailrotor drive shaft were performed using a Vickers diamond pyramid indenter and a 5 kg indentation mass. The Vickers hardness of the component measured 103.3 HV. Using conversion

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<sup>4</sup> IACS is the International Annealed Copper Standard for conductivity and is as a baseline conductivity measurement to compare against other materials.

tables<sup>5</sup> the hardness was transformed to an equivalent tensile strength of approximately 330 MPa (48 ksi). This value was within the nominal strength range for a wrought 5XXX or 6XXX aluminium alloy.

### **1.6.8 Metallography**

A number of sections of shaft material perpendicular and transverse to the fracture surfaces were mounted, polished and etched for microstructural examination. The study revealed an  $\alpha$ -matrix consistent with that of an aluminium alloy. No evidence of environmental induced damage such as intergranular cracking, pitting corrosion, or any discontinuities from the manufacturing process were found that might have contributed to the failure.

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<sup>5</sup> Diamond pyramid Vickers hardness values conversion used as printed in ASTM E140, Table 1.



Shortly after the McDonnell Douglas Hughes M369E departed Archerfield Airport and while in climb to cruise, the helicopter sustained complete failure of the tailrotor drive shaft. The failure lead to total loss of tailrotor thrust, but occurred at an altitude which allowed the pilot to execute an emergency landing manoeuvre.

The ATSB examination revealed that the drive shaft failed from localised buckling that lead to torsional overload and total fracture of the rear tubular structure. The surfaces around the circumferential fracture contained no evidence of prior mechanical rubbing or rotational contact damage. No evidence was found of any pre-existing material defects that might have contributed to the failure. While no engineering drawings or specifications were available, the alloy type comprising the shaft was typical for the application.

The life-limited component had accumulated 5,774.7 flight hours prior to the failure. It was well within the manufacturer's airworthiness limitation that stipulated it should be replaced after accumulating 13,900 hours of service. A search of several databases revealed no history of similar failure occurrences for the MD369-type helicopter indicating that the failure was isolated and infrequent in nature.

Despite the overall serviceability of the tailrotor system and lack of any apparent prior damage to the tail shaft, the factors contributing to the overload event could not be conclusively established. It is likely that some time prior to the failure the component was exposed to a localised transient loading condition above that of its intended design. To produce the overload failure, the tailrotor system must have been exposed to conditions or events capable of producing a significant increase in the rotational resistance of the assembly. Possible events that could have contributed to the initial overload failure may include: a tailrotor impact, a bird strike, failure of the drive shaft bearings or a gross malfunction within the tail/main rotor gearbox system.

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## 3

## FINDINGS

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### 3.1

#### Contributing factors

Failure of the tailrotor drive shaft (P/N 369D25518-501, S/N 009999-3892) from a McDonnell Douglas Hughes 369E, registered VH-INM, revealed that the component failed from torsional overload. Once the shaft structure had buckled and deformed, the shaft sustained a complete fracture close to the rear end of the component.

### 3.2

#### Other key findings

No evidence was found that might indicate a pre-existing fatigue crack had been propagating within the tubular structure prior to its failure. Nor was any evidence of pre-existing mechanical damage found that could have compromised the structural integrity of the item prior to failure.

The factors that contributed to the torsional overload of the drive shaft could not be conclusively established.