ACCIDENT

Aircraft Type and Registration:	MD Helicopters MD900 Explorer, G-CEMS
No & Type of Engines:	2 Pratt & Whitney Canada PW207E turboshaft engines
Year of Manufacture:	2001
Date & Time (UTC):	29 July 2011 at 0801 hrs
Location:	Leeds Bradford Airport
Type of Flight:	Aerial Work
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear forward cross tube fractured, area of fuselage delamination
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	2,235 hours (of which 1,007 were on type) Last 90 days - 43 hours Last 28 days - 14 hours
Information Source:	AAIB Field Investigation

Synopsis

Approximately one minute after landing, and whilst stationary on the ground, the forward cross tube of the helicopter's skid landing gear fractured, damaging the helicopter but not causing any injuries to the crew onboard. The forward cross tube had failed due to a fatigue crack beneath the right side stop clamp. It was determined that although the clamp had not been removed from the cross tube during scheduled maintenance, as required by the Rotorcraft Maintenance Manual, the maintenance instructions were ambiguous regarding the requirement to inspect the area of the forward cross tube beneath the side stop clamps. Two Safety Recommendations have been made.

History of the flight

Prior to departure for an air ambulance flight, ATC cleared the commander to hover taxi the helicopter from its parking position to Hold Y and await further clearance. After an uneventful takeoff and hover taxi the helicopter landed at Hold Y. However, after being stationary for approximately one minute with the engines set at FLIGHT IDLE, a loud "bang" was heard and the helicopter pitched nose down and to the right. The commander shut down both engines and the crew vacated the helicopter without further incident. Once outside, the commander observed that the forward landing gear cross tube had broken close to the right saddle clamp bracket, and the fuselage was in contact with the broken cross tube.

Description of the MD900 landing gear

The MD900 helicopter is equipped with a tubular aluminium alloy landing gear, comprising left and right skid tubes that are supported by fore and aft cross tubes (Figure 1). The cross tubes provide elastic deformation during normal landings and are attached to fuselage fittings by means of four saddle clamp assemblies. The fore and aft cross tubes are restrained from moving laterally by four side stop clamp assemblies (Figure 2), that are attached immediately inboard of each saddle clamp. The internal face of the side stop clamps makes a metal-to-metal contact with the mating cross tube, allowing electrical current to flow in the event of a lightning strike. An electrical bonding strap is secured between the side-stop clamp and the saddle clamp assembly to provide electrical continuity.

The forward cross tube is constructed from drawn 7075 T6 aluminium alloy tubing, with a nominal outer diameter of 2.4” and a nominal wall thickness of 0.350”. After forming and chemical milling operations, the cross tube’s inner and outer surfaces are chemically film-treated to MIL-DTL-5541. The production drawing for the forward cross tube requires that both the inside and outside surfaces of the tube are painted with an epoxy primer, prior to exterior paint finish application. The areas of cross tube beneath the side stop clamps had not been not primed or painted, due to the requirement for electrical bonding to the side stop clamps.

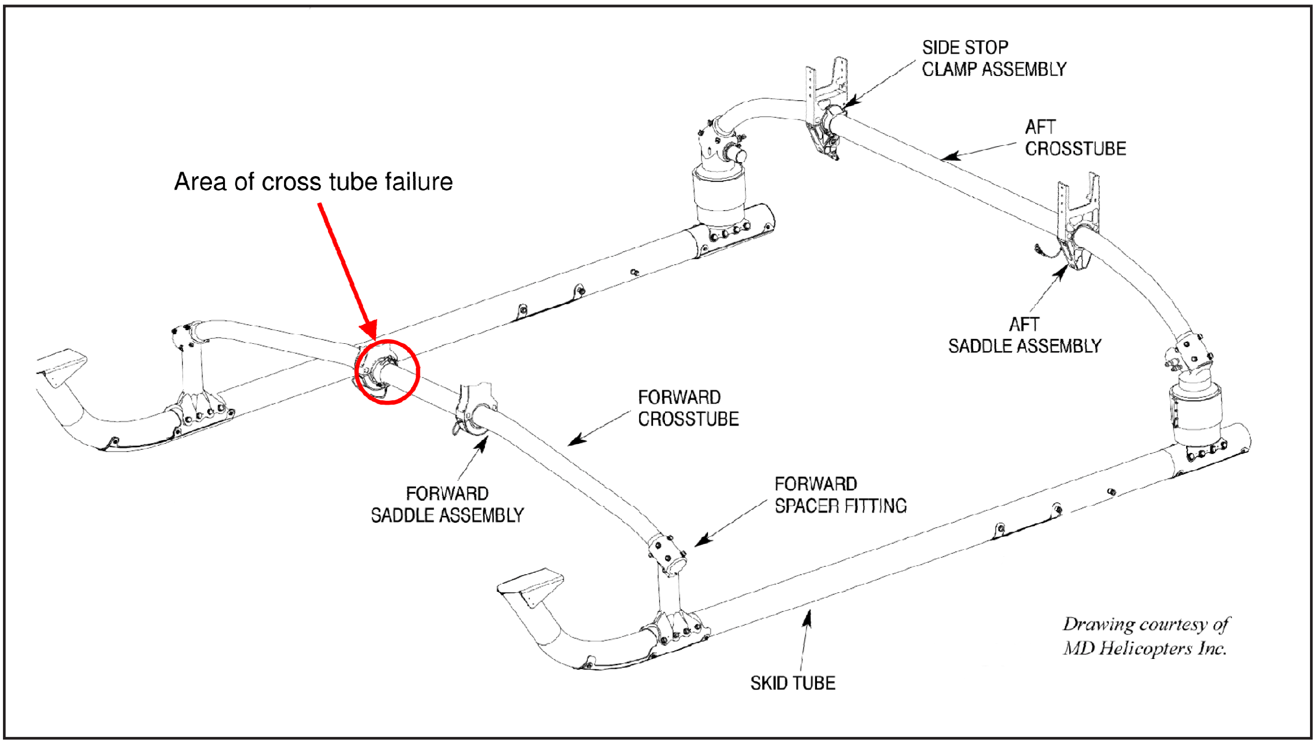


Figure 1

MD900 landing gear showing location of the forward cross tube failure

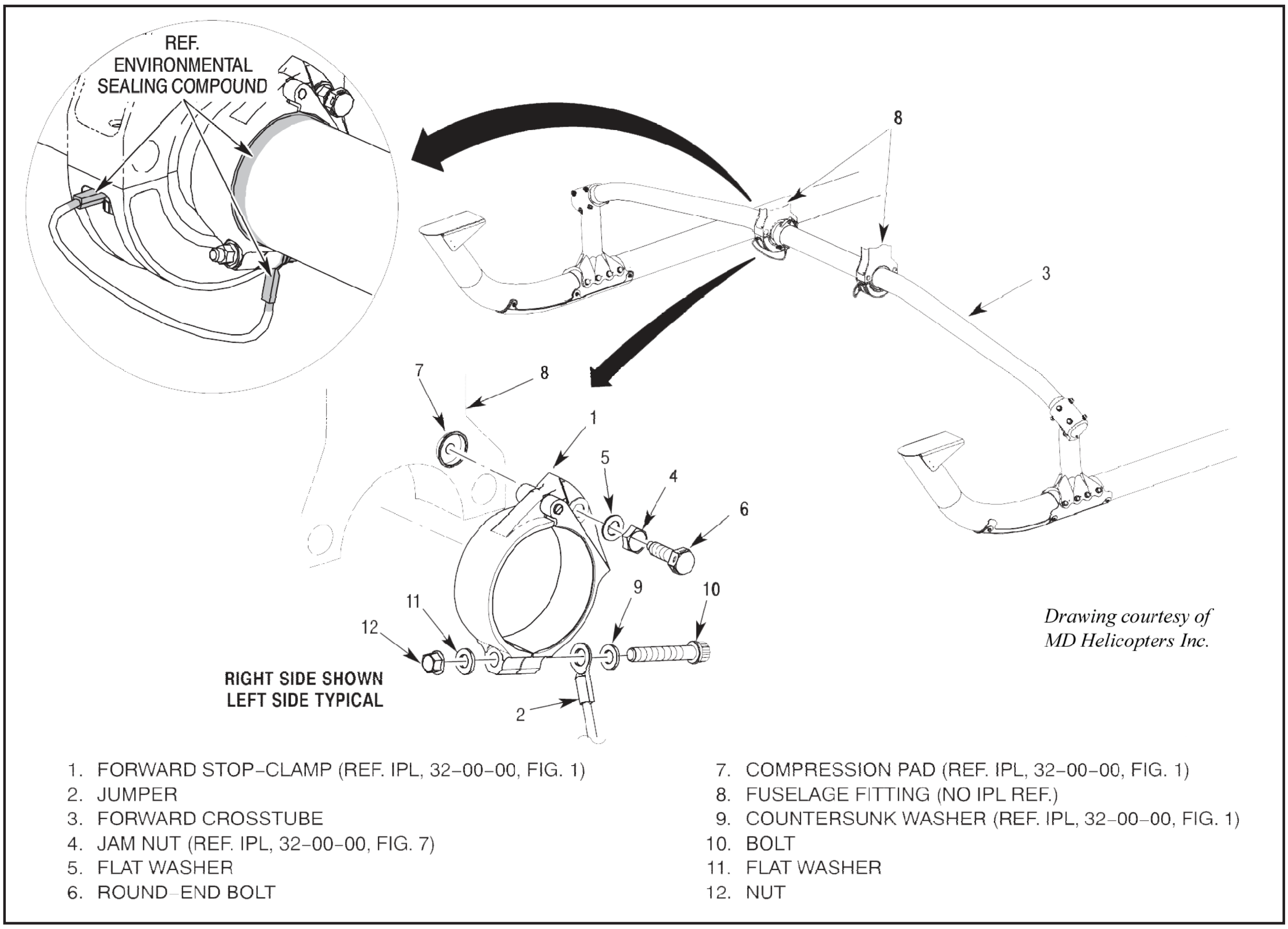


Figure 2

Forward side stop clamp detail

Aircraft damage

The forward cross tube had completely fractured immediately inboard of the right forward saddle assembly and the fracture originated at the lower surface of the cross tube, underneath the side stop clamp. The resulting contact between the helicopter's fuselage and the broken forward cross tube resulted in delamination of the fuselage skin and right keel beam, both of which are constructed from composite materials.

Detailed examination

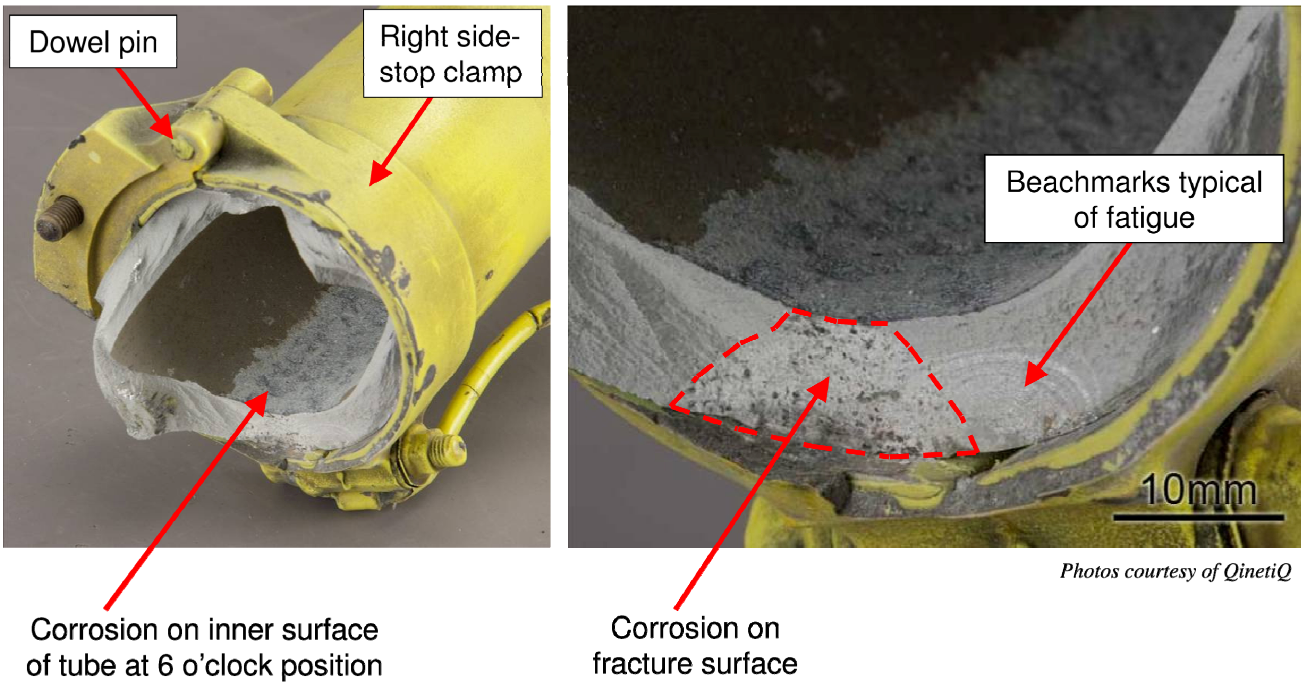
The forward cross tube, complete with the left and right side-stop clamp assemblies still attached, was sent to the AAIB for detailed examination. The inboard side of the fracture surface (Figure 3) exhibited a clear area of fatigue crack propagation, originating at the bottom of the cross tube, approximately 3 mm into the area covered by the side stop clamp. The circumferential length of the fatigue crack at the surface of the tube was 17 mm and the area of fracture surface away from the fatigue region had a dull grey appearance, indicative of tensile overload. The inside surface of the cross tube had not been painted with epoxy primer and was not in conformance with the

MD Helicopters production standard. The cross tube's inside lower surface was significantly corroded and the width of the corroded area decreased towards the outer ends of the cross tube, indicating that an accumulation of moisture had occurred inside the tube around a central low point. Some of the accumulated moisture had penetrated the fatigue fracture, causing a tapered area of corrosion on the fracture surface.

Both the forward cross tube side stop clamps had intact paint covering the environmental sealant around the circumferential joints between the clamp edge and the cross tube. Following removal of both clamps, the paint covering the sealant was examined in detail, revealing a lower layer of yellow paint, covered by an upper layer of lime green paint matching the helicopter's current paint scheme. The lower yellow paint finish was applied when the helicopter was manufactured in July 2001 and the intact paint layers demonstrate that the sealant on the side stop clamps had not been renewed since this date.

Removal of the clamps revealed significant surface corrosion on both the exposed area of the cross tube and on the mating clamp surfaces (Figure 4).

The fatigue crack origin was examined using both visual and scanning electron microscopy (SEM) which showed that, despite the presence of local corrosion pits, the fatigue crack had actually initiated from a shallow, curved machining mark in the tube's outer surface (Figure 5). The SEM analysis showed that the crack had initially propagated in fatigue, with at least 16 separate visible 'beachmarks', before subsequently progressing through a series of five 'static jumps' (Figure 6). A static jump is a ductile overload phenomenon in which a high load event causes a fatigue crack to propagate by localised tensile overload, before reverting back to progressive fatigue propagation under lower cyclical loading conditions. Analysis of the fracture surface away from the fatigue region revealed three 'arrest' marks within the overload failure surface.



Photos courtesy of QinetiQ

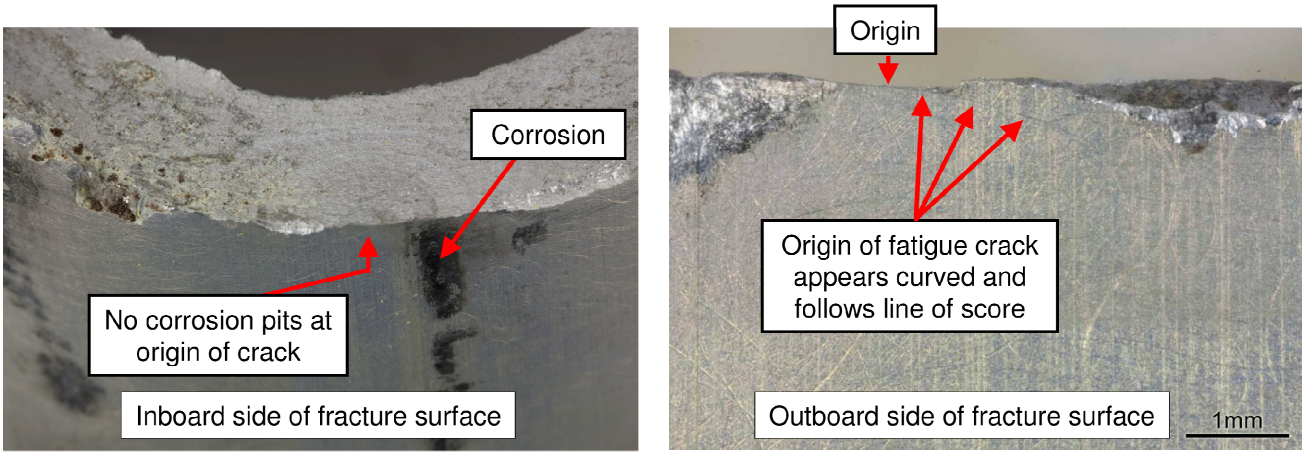
Figure 3

Visual examination of the inboard side of the fracture surface

Photos courtesy of QinetiQ

Figure 4

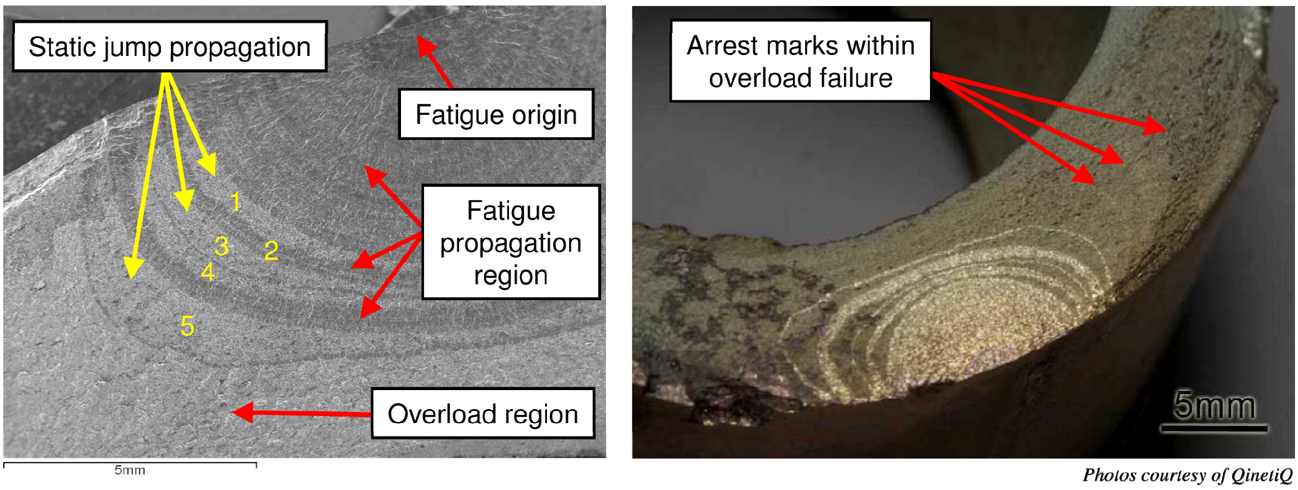
Surface corrosion beneath right side stop clamp



Photos courtesy of QinetiQ

Figure 5

Visual examination of the fatigue crack origin



Photos courtesy of QinetiQ

Figure 6

Propagation of the primary fatigue crack away from the crack origin

A significant number of secondary fatigue cracks were visible adjacent to the primary fatigue crack, with many of these originating from curved surface machining marks (Figure 7).

A 20 mm long section of the cross tube, immediately inboard of the primary fracture surface, was removed and polished to facilitate examination of the material's microstructure. A total of 64 secondary surface cracks were visible in this section, ranging in depth between 16 µm and 290 µm. The section's material characteristics were assessed by hardness testing and energy dispersive X-ray analysis and were determined to be within the 7075 T6 specification for hardness, chemical composition and electrical conductivity. The section exhibited extensive corrosion on the internal surface of the cross tube and in some areas this corrosion was intergranular, which is characteristic of exfoliation.

Maintenance history

The helicopter was built in July 2001 and exported to Indonesia in November 2001, where it was used as a crew transport helicopter in the offshore oil industry. In November 2003, having accumulated 2,294 hours and 9,129 landings, it entered a prolonged period of hangar storage before being exported to the UK in March 2007, for reconfiguration as an air ambulance. The helicopter was repainted in July 2007 into its current colour scheme and had accumulated 3,308 hours and 12,397 landings at the time the accident occurred. The landing gear assembly installed on the helicopter was the original unit fitted during manufacture.

The helicopter manufacturer's records showed one prior occurrence of a crosstube fracturing and this fracture had occurred about 3 inches outboard of the saddle clamp. The failure mode was fatigue, followed by overload, with mechanical damage at the fatigue origin. The

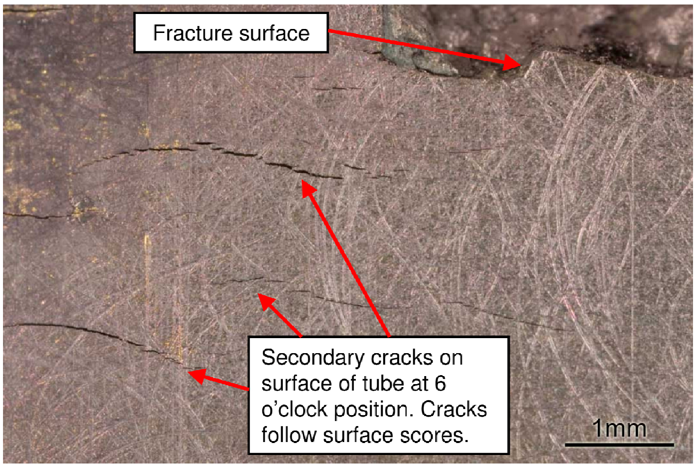


Photo courtesy of QinetiQ

Figure 7

Secondary cracking of the cross tube

manufacturer had not received any reports of cracking of the crosstube or reports concerning the dowel pin hole on the side stop clamp.

Maintenance requirements

Content of the Rotorcraft Maintenance Manual

Chapter 05-20-20 of the Rotorcraft Maintenance Manual (RMM) contains tabulated worksheets summarising the inspections required for completion at the annually recurring Airframe Periodic Inspection Program (APIP). The requirement to comply with RMM instructions during scheduled inspections is stated in Section 2 of this chapter:

> *'This section contains requirements for scheduled inspection. Compliance with the Rotorcraft Maintenance Manual (RMM) information is required, and the manual consulted when using the inspection schedules for specific maintenance activity or inspection requirements and procedure.'*

The worksheet relating to the APIP landing gear inspections is provided in Table 208 in Chapter 05-20-20, and includes the following two tasks that are relevant to detection of a crack in the forward cross tube:

> *'Examine forward and aft cross tubes, fuselage attach fittings, and saddle clamps for damage, indication of failure and condition'*

> *'Examine side stops for damage and condition'*

Both of these tasks further refer to Chapter 32-00-00 of the RMM for additional detailed instructions.

Inspection of the forward side stop clamp assemblies

Section 3A of Chapter 32-00-00 describes the procedure to be carried out to inspect the forward side stop clamp assemblies. In addition to an external visual inspection, to identify damage and missing hardware, tasks 6 and 7 of the procedure require removal of the side stop clamps from the forward cross tube to facilitate examination of a dowel pin hole. The side stop clamps are an assembly of two components joined at a hinge by means of a dowel pin:

> *'(6). Remove side-stop clamps (ref. Section 32-00-00, Removal/Installation). (7). Examine dowel pin hole for damage, deformation and corrosion.'*

The procedure does not contain an instruction to inspect the area of the forward cross tube revealed once the side stop clamps are removed, and whilst step 6 of the procedure requires removal of the side stop clamps, for access, there is no positive instruction given regarding their re-installation. Re-installation of the side stop clamps is covered in Section 1B of Chapter 32-00-00 and requires, amongst other tasks:

> *'(2)(f). Environmentally seal jumper connection and perimeter of forward stop-clamp with sealing compound (C211) (ref. CSP-SPM, Section 20-50-00)'*

Inspection of the forward cross tube

Section 4B of Chapter 32-00-00 contains the inspection procedure to be followed for the forward cross tube, which includes the following task:

> *'(1). Examine the forward cross tube for cracks, dents, gouges, and corrosion. (a) No cracks, dents, gouges or corrosion permitted.'*

Whilst this task requires that the forward cross tube is inspected, it does not explicitly state that the area beneath the side stop clamps is made accessible for inspection, at this stage, by removal of the clamps.

Section 4B also contains instructions on measurement of the distance between the ends of the forward and aft cross tubes, whilst the helicopter is raised on jacks, to determine whether permanent deformation of the cross tubes has occurred during a heavy landing. Maximum allowable values of this 'cross tube spread' are provided to allow a comparison to be made.

Content of the customised Maintenance Program

Following import to the UK, the helicopter was maintained to a customised maintenance program that was closely based on the manufacturer's APIP program, together with certain additional Special Inspection Schedules relating to additional hourly and calendar-based inspection requirements. The customised program was approved under the maintenance organisation's EASA Part 145 approval and contained worksheets listing maintenance *'Actions Required'* for individual components. The worksheet task relating to the forward and aft cross tubes was:

> *'ITEM 0115: LANDING GEAR – Forward and Aft Crosstubes; Fuselage attachment fittings and saddle clamps. Inspect for apparent defects, evidence of failure and general condition.'*

The worksheet task relating to the side stop clamps was:

> *'ITEM 0117: LANDING GEAR – Side Stop Assemblies and attaching hardware; Adjustment bolts; Stop Pads; Bonding jumpers. Inspect for apparent defects and general condition. Visually inspect for general condition and security. Inspect for general condition and proper mechanical connection.'*

Both the above worksheet tasks listed Chapter 32-00-00 of the RMM as the *'Publication Reference'*, but neither made specific mention of the RMM requirement to remove the side stop clamps during maintenance.

Maintenance actions

The helicopter's most recent annual maintenance inspection occurred in April 2011 and the work was certified by an EASA Part 66 B1 licensed engineer. The maintenance workpack records were examined and they showed that all tasks on the worksheets relating to the landing gear were initialled and stamped to indicate completion by the certifying engineer. The landing gear 'cross tube spread' measurements for both forward and aft cross tubes were certified as being within RMM limits; the actual spread measurements were not recorded and there was no requirement in the RMM to do so.

Discussion

Nature of the failure of the forward cross tube

The large number of additional fatigue cracks identified in the vicinity of the main fatigue crack indicates that there had been either a reduction of the fatigue strength of the cross tube material, or higher than expected tensile stress levels in this area of the cross tube, or a combination of these effects. The fatigue strength of 7075 T6 aluminium alloy has been shown to be sensitive to exposure to saline environments[1], and the helicopter had operated in the offshore environment for two years between 2001 and 2003, during which the sealant between the cross tube and side stop clamp components had not been renewed as required by the RMM. The presence of corrosion on the unpainted cross tube surface, beneath the side stop clamps, demonstrates that the sealant between the components was insufficient to protect them from moisture ingress.

The investigation could not accurately determine the age of the main fatigue crack due to the difficulty of correlating the fatigue beachmarks with landing cycles, loading applied to the cross tube during any one landing event being variable. Whilst it is considered probable that the main fatigue crack had been present in the cross tube for a considerable period of time, it is uncertain whether a visual examination of the tube surface would have been sufficient to detect the crack before it reached a critical length, prior to the overload failure of the tube. The following Safety Recommendation is therefore made:

Footnote

[1] B. Sarker, M. Marek and E.A. Stacke, Journal of Metallurgical and Materials Transactions A, p. 1939, Vol 12A, 1981.

Safety Recommendation 2012-004

It is recommended that the Federal Aviation Administration require MD Helicopters to determine a suitable inspection method and interval for periodic detailed examination of the landing gear cross tubes on the MD900 helicopter.

Removal of the side stop clamps during inspections

Had the side stop clamps been removed during the previous annual maintenance inspection, it is likely that the presence of surface corrosion on the cross tube would have been readily apparent, triggering remedial action as required by the *'Corrosion Removal'* section of the helicopter's Standard Practices Manual. It is also possible that the fatigue crack in the cross tube may have been detected by visual inspection of the cross tube at this time, as the inspection occurred only 169 landings before the eventual overload failure of the cross tube.

The intact paint on the environmental sealant between the side stop clamps and the forward cross tube indicates that the clamps had not been removed since the helicopter was built, approximately ten years prior to the accident. Therefore the failure to remove the side stop clamps was not an isolated incident.

Whilst the lack of a specific prompt to remove the side stop clamps on Item 0117 of the customised maintenance program worksheet is considered to be a contributory factor, the worksheet correctly referenced the definitive task instructions in Chapter 32-00-00 of the RMM, which required removal of the side stop clamps.

Ambiguity in the RMM maintenance instructions

The RMM is ambiguous with regard to inspection of the area of the forward cross tube beneath the side stop clamps. Section 3A of Chapter 32-00-00 required the clamps to be removed to allow examination of each clamp's dowel pin hole, but no requirement is stated for inspection of the inside surface of the clamp or the mating surface of the cross tube, or for the clamp's reinstallation. Section 4B of Chapter 32-00-00 required that the cross tube was inspected for *'cracks, dents, gouges and corrosion'* but the maintenance instructions did not explicitly state that the side stop clamps had to removed during this part of the inspection. The following Safety Recommendation is therefore made:

Safety Recommendation 2012-005

It is recommended that the Federal Aviation Administration require that MD Helicopters amend the MD900 Rotorcraft Maintenance Manual to require visual examination of the area of forward and aft cross tube, exposed when the forward and aft side stop clamps are removed, as part of the periodic maintenance schedule.

Safety actions

In addition to the above Safety Recommendations, the manufacturer is investigating the omission of epoxy primer on the inside of the forward cross tube, to determine whether the non-conformance was an isolated occurrence.