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Robert A. Feeler, editorial coordinator

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On the cover: Eurocopter BK 117

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Fatal Accident Shows Risk of Using Blind Rivets

In-flight separation of the vertical fin from a Eurocopter BK 117 was accelerated by the use of blind rivets in place of solid rivets during installation of a replacement part.

—

Bart J. Crotty

On April 15, 1997, the crew lost control of a Eurocopter BK 117-B2 while departing from the 60th Street heliport, New York City, New York, U.S. The helicopter, owned and operated by Colgate-Palmolive Co. and being flown on a visual flight rules flight plan under U.S. Federal Aviation Regulations (FARs) Part 91, descended into the East River and sank. One passenger was killed, the other passenger and the pilot-in-command received serious injuries, and the copilot received minor injuries.

The accident report by the U.S. National Transportation Safety Board (NTSB) said that the probable cause of the accident was "the fatigue failure of the vertical fin, accelerated by the installation of blind rivets in lieu of solid rivets in the replacement of the [mount support for the yaw stability-augmentation system (SAS)], which resulted in the loss of helicopter directional control and collision with the terrain (water)." (The yaw-SAS-mount support was a 0.04-inch [1-millimeter] thick, 11-inch by 14-inch [28-centimeter by 36-centimeter] sheet-metal plate on the left side of the vertical fin.)

The report said that factors contributing to the accident were a lack of

information in the manufacturer's maintenance manuals about repairs to the yaw-SAS-mount support and the design of the vertical fin, which was susceptible to fatigue cracking.[1]

The report said that the upper half of the helicopter's vertical fin separated from the aircraft because of fatigue cracking. A laboratory examination of the wreckage revealed multiple fatigue cracks in the vertical-fin skin, frame assembly, stiffener rib and spar, and compression and deformation on the right side of the vertical fin.

"Five distinct cracks with independent initiations near blind-rivet holes were found," the report said. "For two segments, the origins were under the heads of blind rivets."

A skin crack on the left side of the vertical fin was 5.5 inches (14 centimeters) long; all but one inch (2.54 centimeters) of the crack was beneath the yaw-SAS-mount support, which had been replaced in 1992 because of a crack.

The left-hand frame assembly was fractured about 0.5 inch (12.7 millimeters) below the plane of the skin fracture. The fracture face had "a polished appearance," the report said, "and further examination did not uncover the original fracture features."

The stiffener rib was fractured about 0.5 inch above the level of the skin break, "through a blind rivet hole in one leg and a lightening hole in the other leg. The fatigue initiated at multiple origins on the outboard face of the rib, progressed through the thickness and away from the hole, in the forward and aft directions. About half of the rib was fractured in fatigue, with the remainder in tensile overstress."

The report said that the fracture face of the crack on the spar cap, which intersected a blind-rivet hole, occurred "in an area of the spar where a small transverse flange on the aft edge of the spar cap had been machined away to provide clearance for the lower-actuator-mount sheet metal. … Optical examination found extensive damage and polishing to the fracture faces consistent with fretting and recontact between the faces. No recognizable fracture-mode features were visible."

The report said that the spar web crack was a fatigue crack that began at a solid-rivet hole.

The accident helicopter had accumulated 4,186 flight hours and 15,561 flight cycles at the time of the accident. Colgate-Palmolive acquired the helicopter new in December 1989 as a B1 model and later upgraded the B1 to a B2 model. The helicopter was maintained in accordance with the manufacturer's inspection program, which included a progressive maintenance program and phased inspections at 50-hour intervals.

When a Colgate-Palmolive maintenance technician replaced the yaw-SAS-mount support in 1992, the helicopter had a total airframe time of 1,694 hours. The original yaw-SAS-mount support had been installed by the manufacturer using solid rivets; the replacement mount support, which was obtained new from the manufacturer, was installed on the upper part of the vertical fin, halfway between the intermediate gearbox and the 90-degree gearbox, using CherryMax rivets (part number CR3243, also designated as National Airspace Standard NAS9304B), manufactured by Textron Aerospace Fasteners of Santa Ana, California, U.S. They were 4/32-inch (3.2-millimeter) blind rivets, oversized by 1/64 inch (0.4 millimeter).

The Colgate-Palmolive maintenance technician who replaced the yaw-SAS-mount support said that he used blind rivets because the presence inside the vertical fin of hydraulic lines leading to the SAS-yaw-servo actuator limited work space. Thus, the use of solid rivets would have been difficult unless the hydraulic lines had been removed.

The report said, "The investigation revealed that the majority of the rivets used with the [yaw-SAS-mount] support were easily accessible. … To improve accessibility to certain rivets, it was necessary to remove the hydraulic lines."

The report said that the maintenance technician, who held a U.S. Federal Aviation Administration (FAA) airframe and powerplant (A&P) mechanic certificate and inspection authorization (IA), provided no specific reference for use of the blind rivets.

The Eurocopter BK 117 maintenance manual contained no specific instructions for replacing the yaw-SAS-mount support or for substituting blind rivets for solid rivets, but Eurocopter referred maintenance personnel to FAA Advisory Circular (AC) 43.13-1A, "Acceptable Methods, Techniques and Practices – Aircraft Inspection and Repair" for guidance on repairs that were not discussed in the manual.

The maintenance technician said that the NAS numbers cited in AC 43.13-1A for blind rivets were outdated and that CherryMax rivets were considered "the same as solid rivets and had been used in many applications as a replacement for solid rivets."

The Colgate-Palmolive director of maintenance, who held an FAA A&P certificate with IA and who approved the helicopter for return to service, said that the NAS numbers in the AC were outdated and that he "believed the rivets were OK for use but did not cross-reference them specifically."

AC 43.13-1A stated, "Blind rivets in the MS-20600 through MS-20603

series rivets and the mechanically locked stem NAS 1398, 1399, 1738 and 1739 rivets [numbers that designate CherryLock rivets, which predated CherryMax rivets] may be substituted for solid rivets in accordance with the blind rivet or aircraft manufacturer's recommendations. They should not be used where the looseness or failure of a few rivets will impair the airworthiness of the aircraft."

[Other FAA publications, including AC 65-9A, "Airframe and Powerplant Mechanics General Handbook," Chapter 6, and AC 65-15A, "Airframe and Powerplant Mechanics Airframe Handbook," Chapter 5, both issued in 1976, said, "Self-plugging (mechanical lock) rivets display all the strength characteristics of solid-shank rivets and in most cases can be substituted rivet for rivet."[2,3] (Self-plugging mechanical lock rivets are one of three types of blind rivets; CherryMax rivets and CherryLock rivets are self-plugging mechanical lock rivets.)]

Nevertheless, the accident report said, "although maintenance personnel from Colgate-Palmolive reported that CherryMax rivets could be substituted for CherryLock rivets, a check with Textron Aerospace Fasteners and the FAA failed to produce any written documentation authorizing the substitution."

The accident report said that the vertical-fin spar could be inspected for cracking only by removing the tail-rotor drive shaft and the yaw-SAS actuator. The BK 117 maintenance manual originally required their removal every 1,200 flight hours. Eurocopter subsequently increased the inspection interval, first to 2,400 flight hours and later to 3,600 flight hours.

Nevertheless, Colgate-Palmolive maintenance personnel said that they continued to conduct their inspections every 1,200 flight hours and that they had conducted two inspections after the replacement of the yaw-SAS-mount support. The last inspection was conducted in April 1996, at 3,600 flight hours.

The report said that the "holder, left-hand assembly," located on the vertical fin about six inches (15 centimeters) above the fatigue crack, had been installed incorrectly after the tail boom was reskinned in December 1990. Colgate-Palmolive maintenance personnel said that the repair, which was performed by a contracted FAA-certified repair station, was necessary because of cracking near the intermediate gearbox.

An FAA engineering office said that an incorrectly installed holder "would have negligible effect on the initiation or propagation of the fatigue cracks found in the tail spar and skin of the accident helicopter."

Nevertheless, the engineering office said, "If the holder was installed

incorrectly … the stress concentration would increase at the mounting support cutout due to plate bending and clamp up-loads on the fasteners."

The NTSB metallurgist participating in the investigation said that a drawing (drawn after the accident) submitted by Colgate-Palmolive showed that the crack on the cutout of the yaw-SAS-mount support had been over the holder, left-hand assembly. Colgate-Palmolive said that the original yaw-SAS-mount support was not available for examination and that no photographs existed of the unit. Therefore, the location of the crack could not be confirmed.

After the accident, Eurocopter issued Alert Service Bulletin (ASB) MBB-MK117-30-106, and FAA issued Airworthiness Directive (AD) 97-09-16 to require "immediate and repetitive visual inspections" of the vertical-fin spar on BK 117 helicopters to check for "cracks, loose rivets and other anomalies." The AD also instructed operators to inspect visually the skin and the left-hand frame and right-hand frame. The inspections revealed cracks in 10 [of about 125] BK 117s in the United States, including one helicopter that had been operated by Colgate-Palmolive but had been traded before the accident. Eight of the 10 helicopters had cracks in the vertical-fin spar. One helicopter had a crack in the left-hand frame assembly. The location of the crack in the tenth helicopter was not reported.

Revisions of the ASB instructed operators to repair cracks in the vertical-fin spar and the left-hand frame and right-hand frame and — later — to reinforce the vertical-fin spar, frames and adjacent skin. An ASB revision in December 1997 deleted a reference that had allowed use of blind rivets in repairs or modifications of the vertical-fin spar.

FAA AD 97-20-16 mandated the structural repairs, modifications and repetitive inspections recommended by the revised ASBs, and AD 98-24-13 prohibited use of blind rivets during repairs or modifications of the vertical-fin spar.

"Inspections of BK 117s resulting from the FAA … ADs [and similar directives from authorities in other countries] revealed that at least four other helicopters worldwide had developed fatigue cracks in the vertical-fin spar," NTSB said in the safety recommendation issued to coincide with the public release of the final accident report.

"In addition, Eurocopter reports indicate that before the Colgate-Palmolive accident, seven helicopters had developed fatigue cracking at various cross-sections of the vertical-fin spar. However, several of the fatigue cracks were found in areas not

specifically addressed by the inspection requirements of AD 98-24-13. Therefore, the Safety Board remains concerned that there may be additional incidents of fatigue cracking of BK 117 vertical fins. Further, on the basis of its design review of the BK 117 vertical fin, the Safety Board is also concerned that normal visual inspection techniques … may not be adequate to detect cracking damage in the underlying areas of the spar or leading-edge skin."

Therefore, NTSB recommended that FAA conduct a fatigue evaluation and damage-tolerance analysis of the vertical fin to ensure that inspection requirements prescribed in the AD are adequate to detect the growth of cracks in the underlying areas of the modified spar and the leading-edge skin and to ensure that the vertical-fin spar is "not susceptible to fatigue failure beyond those areas specifically identified by AD 98-24-13. If the susceptibility is not so limited or the inspection requirements are not adequate, the AD should be superseded to ensure that all fatigue cracks will be detected."

In the recommendation, NTSB said that, although the CherryMax CR3243 blind rivet "is generally accepted as a replacement for the NAS 1738B blind rivet, no FAA guidance confirms the interchangeability of these rivets."

FAA's AC 43.13-1B, issued in September 1998 to supersede AC 43.13-1A, provides no information about the joint fatigue life of materials when they are joined with blind rivets.

"Postaccident testing conducted by Textron Aerospace Fasteners … and earlier testing conducted by Eurocopter consistently demonstrated that the joint fatigue life of materials fastened with blind rivets is less than the joint fatigue life of the same materials fastened with solid rivets," NTSB said. "The Safety Board is concerned that other maintenance personnel may install blind rivets in applications where solid rivets are required, thereby reducing the structural fatigue life of an airframe."

NTSB said that FAA should "issue a maintenance alert to all certificated airframe mechanics and inspectors to notify them of the circumstances of this accident and to inform them of the hazards associated with the installation of blind rivets."

NTSB also recommended that FAA:

- Revise AC 43.13-1B to require that operators substitute fastener types "only when the application has been specifically authorized by the airframe manufacturer or a representative of the [FAA]"; and,

- Revise FARs Part 43, Appendix A, to classify repairs that involve

the substitution of fastener types as major repairs.♦

[Editorial note: This article, except where specifically noted, was based on U.S. National Transportation Safety Board (NTSB) Factual Report NYC97FA076, NTSB Brief of Accident and NTSB Safety Recommendation A-00-46 through -50. The 234-page factual report includes photographs.]

References

1. U.S. National Transportation Safety Board (NTSB) accident report no. NYC07FA076 said that an additional factor was the lack of an adequate passenger briefing. There were no evacuation cards in the cabin, and several regular passengers on company helicopters said that they were not aware of the procedures for opening the main cabin door, the location and procedures for opening emergency exits and the location and procedures for use of personal flotation equipment. The passengers also said that passenger briefings were given only to new passengers before their first flight on the helicopter. NTSB recommended that the U.S. Federal Aviation Administration (FAA) require that passengers in large and turbine-powered multi-engine helicopters receive passenger briefings similar to those required for passengers in large and turbine-powered multiengine airplanes.
2. FAA. Advisory Circular (AC) 65-9A. "Airframe and Powerplant Mechanics General Handbook," Chapter 6. 1976.
3. FAA. AC65-15A. "Airframe and Powerplant Mechanics Airframe Handbook," Chapter 5. 1976.

About the Author

Bart J. Crotty is an airworthiness, maintenance and safety consultant and chairman of the maintenance human factors committee of the International Society of Air Safety Investigators. He is a former U.S. Federal Aviation Administration (FAA) airworthiness inspector and trainer and a former International Civil Aviation Organization airworthiness specialist. Crotty has worked for repair stations, airlines, a large aircraft manufacturer, law firms, consulting firms, a safety organization and several national civil aviation authorities. His career spans 39 years, with about half of that time in countries other than the United States. He has an FAA airframe and powerplant mechanic certificate and a bachelor of science degree in aeronautical engineering. Crotty resides in Springfield, Virginia, U.S.

NTSB Recommends Alternative to Nickel-Cadmium Plating

The U.S. National Transportation Safety Board (NTSB) has cited two engine failures in recommending a requirement for an alternative to nickel-cadmium plating to protect steel rotating engine parts against corrosion.

The recommendation to the U.S. Federal Aviation Administration (FAA) followed an Oct. 7, 1998, accident in which a Continental Airlines Boeing 727 had an uncontained failure of its no. 2 (center) engine, a Pratt & Whitney JT8D-9A, during a takeoff roll at Miami International Airport, Florida, U.S.

"The captain reported that while he was advancing the engine power levers, he heard a loud bang and immediately retarded the power levers, rejecting the takeoff," the safety recommendation said.

The airplane was stopped, the flight crew discharged one fire bottle, and all crewmembers and passengers deplaned safety. No injuries were reported.

The NTSB investigation revealed that fragments of the no. 2 engine's eighth-stage high-pressure compressor (HPC) hub had penetrated the engine, the cowlings and the airplane's vertical stabilizer.

"Investigators determined that the trajectory of the liberated hub fragments had come within inches of the rudder control cables," the safety recommendation said. "Pieces of the engine and cowling were recovered from the runway and surrounding areas."

Airline records showed that the eighth-stage hub had accumulated 15,539 cycles, including 176 cycles since its last overhaul. The hub's published life limit is 20,000 cycles.

During the last overhaul, nickel-cadmium plating was applied. The JT8D engine manual and overhaul standard practices manual require that the plating process be accomplished by coating the base material (steel) with a layer of nickel 0.0004 inch to 0.0007 inch (0.010 millimeter to 0.018 millimeter) thick, applying a layer of cadmium 0.0001 inch to 0.0002 inch (0.002 millimeter to 0.005 millimeter) thick and then baking the hub for one hour at about 640 degrees Fahrenheit (338 degrees Celsius).

A metallurgical examination revealed that the primary fracture of the hub stemmed from a crack that extended from the rim radius partially into the bore.

"The fracture-initiation site contained a significant amount of cadmium in contact with the base material and on the fracture surface, indicating that the hub failed because of cadmium embrittlement," the safety recommendation said.

"The source of the cadmium was the [nickel-cadmium] plating on the exterior surface of the hub. Analysis of the plating on the multiple cross sections through the hub revealed primarily a single layer of diffused [nickel-cadmium plating] ranging from 0.00008 inch to 0.00019 inch [0.002 millimeter to 0.005 millimeter] thick and no pure nickel layer adjacent to the steel surface."

The exact thickness of the initial layer of nickel could not be determined, but the thickness was less than required by the JT8D manuals.

"This deficiency suggests that the nickel-thickness inspection specified in the maintenance manual was either omitted or performed incorrectly," the safety recommendation said.

During the investigation, NTSB learned that a customer audit of the facility that performed the nickel-cadmium plating procedure had revealed that the layer of nickel was being inspected visually but was not being measured, as required. An NTSB employee also witnessed an electrical malfunction in a nickel-plating tank that prevented sufficient nickel from being applied, the safety recommendation said.

The recommendation said that a previous uncontained engine failure on a United Airlines Boeing 737 during takeoff from O'Hare International Airport, Chicago, Illinois, U.S., also involved an improperly plated part. That accident prompted NTSB to recommend revision of the plating guidelines. In response, FAA issued Flight Standards Information Bulletin for Airworthiness 98-11, directing maintenance inspectors to perform repair station audits to ensure that proper plating procedures are followed.

The recommendation said that United Airlines has discontinued voluntarily the use of nickel-cadmium plating and has begun using Sermetel, an aluminum-based paint approved for use as an alternative to nickle-cadmium in the plating process. The airline believes that Sermetel provides better protection against corrosion and erosion.

"The board considers the use of such alternative corrosion protection

methods important in the effort to prevent failures of steel rotating parts in turbine engines," the safety recommendation said. "Therefore, the board believes that the FAA should require the use of alternative corrosion-protection methods instead of [nickel-cadmium] plating on steel rotating engine parts to eliminate the hazards introduced by improper [nickel-cadmium] plating."

The earlier FAA action "does not appear to be sufficient in preventing engine parts from being improperly plated during routine operations when an inspector is not present or if the process is momentarily left unattended," the safety recommendation said.

"Further, the events discussed in this letter suggest that such improper [nickel-cadmium] plating techniques may continue to be performed in industry and that maintenance personnel may not be receiving adequate initial and recurrent training in the … plating process."

NTSB also recommended that FAA issue a flight standards information bulletin to require principal maintenance inspectors to ensure that facilities performing nickel-cadmium plating have a training program for the process.

Changes Ordered in Landing Gear on Airbus A300-600 Models

The U.S. Federal Aviation Administration (FAA) has ordered modification of the electrical looms of the nose landing gear and the main landing gear on Airbus Model A300-600 airplanes.

The FAA airworthiness directive (AD), which took effect June 16, 2000, also requires changes in the rotor-shaft attachment on tachometers for the nose landing gear and main landing gear. The AD requires that operators of the aircraft complete the modifications within 180 days.

FAA said that the modifications are needed "to prevent erratic operation of the wheel tachometers, which could result in degradation of the braking performance and possible increased landing roll."

The modifications must be performed in accordance with Airbus Service Bulletin A300-32-6069, Revision 1, or Airbus Service Bulletin A300-32-6077, Revision 1.♦

Urethane Adhesive Bonds Thermoplastics, Metals

A new urethane adhesive has been developed for bonding thermoplastics, fiberglass, glass and metals, the manufacturer said.

Ciba Specialty Chemicals, Performance Polymers' Uralane 6100-A/B clear urethane can be applied without sanding or other surface preparation. The urethane gels in two minutes to three minutes, can be handled after one hour and is cured after two days at room temperature or two hours at 150 degrees Fahrenheit (66 degrees Celsius).

The urethane is designed to produce durable, invisible bond lines in the assembly of aircraft parts and in other uses, the manufacturer said.

For more information: Maria Pate, Ciba Specialty Chemicals, 5121 San Fernando Road West, Los Angeles, CA 90039, U.S. Telephone: +1 (818) 265-7210.

Space-saving Switch Developed for Use In Avionics

A compact switch has been developed for the avionics industry to give users a linear-activated switch function with either momentary (spring return) action or detented (push-pull) action, the manufacturer said.

The linear function makes the switch suitable for use for annunciator panel tests, transponder push-to-identify applications and global positioning system function selections. The switch is available with single shafts or concentric shafts.

For more information: Janco Corp., 3111 Winona Ave., Burbank, CA 91504, U.S. Telephone: +1 (818) 846-1800.

Shears Have Serrated Edge for Cutting Kevlar Fibers

Shears have been developed with a serrated edge on one blade for cutting Kevlar fibers, the manufacturer said.

Kevlar Shear

The Xuron Model 9180 Kevlar Shear has cushioned rubber grips and a return spring that opens the cutting head after every cut. The shears have a serrated edge to prevent fibers from sliding and a sharp edge for cutting. The shears are designed for use on fiber optic cables and other cable insulations.

For more information: Abby Robey, Marketing, Xuron Corp., 62 Industrial Park Road, Saco, ME 04072, U.S. Telephone: +1 (207) 283-1401.

Charger/Analyzer Services All Battery Chemistries

The Universal 60 battery charger and battery analyzer offers standard features and an ability to service all battery chemistries and to provide on-site self-calibration, the manufacturer said.

The Universal 60 has digital-current settings, and its design enables the Universal 60 to charge batteries and discharge batteries at specified current settings of up to 60 amperes.

Universal 60 Battery Charger

For more information: Christie Electric Corp., 18120 South Broadway, Gardena, CA 90428, U.S. Telephone: +1 (310) 715-1402.

Fast-curing Chemical Adhesive Seals Screw Threads

The Precote screw-locking and thread-sealing adhesive system uses a microencapsulation process to prevent premature hardening because of chemical reactions to moisture or solvent penetration, the manufacturer said.

Precote Screw-locking and Thread-sealing Adhesive System

The chemical adhesive for fasteners can be applied to internal threads or external threads of fasteners or nuts and to thread sizes M4 and larger. The adhesive is available in several grades for thread-sealing and screw-locking under varying conditions.

For more information: Nylok Fastener Corp., 15260 Hallmark Drive, Macomb, MI 28042-4007, U.S. Telephone: (800) 791-7101 (U.S.) or +1 (810) 786-0100.♦

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