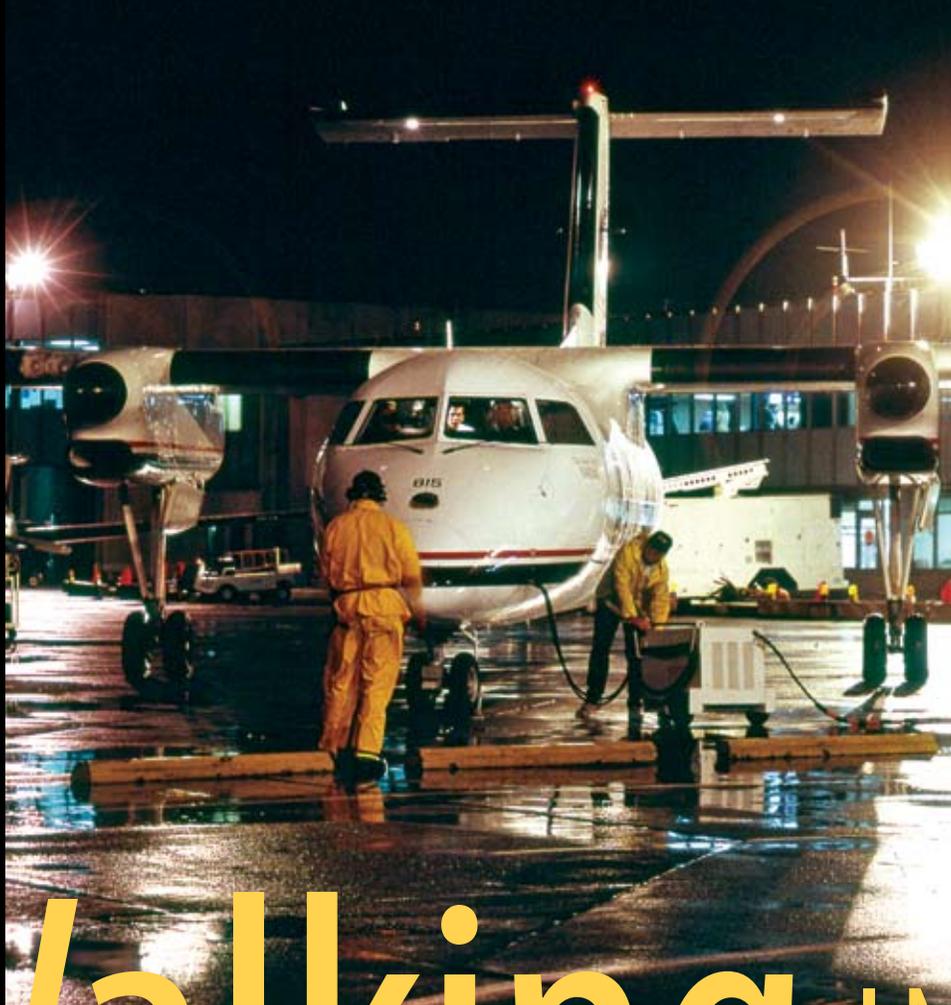


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Walking INTO

Accidents involving human contact with propellers and rotor blades persist, despite safety efforts to prevent them.

BY CLARENCE E. RASH

People continue to come into contact with spinning propellers and rotor blades, often with fatal consequences, even though the danger they represent is well known. Although not common, these accidents continue to claim flight crewmembers, passengers and ground personnel. Most are preventable.

Aircraft manufacturers and operators have implemented a variety

of paint schemes to increase blade conspicuity — visibility — and have developed safety programs to emphasize propeller and rotor-blade hazards.

“Constant care and vigilance [are] required to keep the number of ... accidents at a minimum,” the Australian Civil Aviation Safety Authority (CASA) said in a 2003 advisory circular that discussed the prevention of injuries caused by spinning propellers and rotor blades.¹

The primary risk presented by a spinning blade is that it is difficult — often impossible — to see. In addition, noise from the engine and slipstream/rotor downwash may obscure noise from the blades.

“It is often difficult for a pilot to appreciate the level of confusion that a non-aviator may suffer in the vicinity of an aeroplane with its engine(s) running,” CASA said. “The area to the rear

of an aircraft is where slipstream and noise are most evident, while the front of the propeller area may be relatively quiet. ... Pilots of high-wing singles or twins have to be particularly aware of the risk of a passenger moving from the exit doors forward ... toward the propellers. Pilots of helicopters have to be alert to the possibility of people walking into the tail rotor while focusing on the engine and main-rotor disc when approaching or leaving the cabin."

Propeller tip speeds — which approach the speed of sound during take-off — are dangerous even at the slower speeds involved in ground operations. For example, at typical engine idling

the airplane and — after being told that the wheel chocks had been installed on the left side of the airplane — feathered the right (no. 2) propeller. The captain said that he heard "three or four quick thumps" and was signaled to shut down the right engine.³

"When he exited the aircraft, he saw the ramp service employee lying beneath the aircraft," the report said. "An employee on the ramp [later] stated that the ramp employee involved walked outside of the left wing with two chocks toward the nose of the aircraft. She reported that he walked to the nose landing gear, slowed down and then continued walking around to the other

U.S., in which the pilot of a Beech C35 Bonanza was killed as he hand-propped his airplane.⁴

None of the airplane's wheels had been chocked in front, and the ground was damp after heavy rain the previous evening, the report said. The pilot tried unsuccessfully to start the engine with the electric starter, then hand-propped it.

"The engine fired, and the propeller spun, hitting the pilot," the report said.

Spinning helicopter main-rotor blades have unique risk characteristics because the space occupied by the rotor blades is large — with a typical 40-ft (12-m) rotor-disc span that extends as

Trouble



speeds of 1,000 to 1,200 revolutions per minute (rpm), propeller tip speeds are 200 to 300 mph (322 to 483 kph) or more.²

One common scenario for propeller-strike injuries and deaths involves maintenance and ground personnel working around airplanes.

For example, a ramp service employee received serious injuries when he was struck by a rotating propeller blade on a Saab-Scania 340B at General Mitchell International Airport in Milwaukee on Nov. 13, 2004. A report by the U.S. National Transportation Safety Board (NTSB) said that the captain recalled that he had shut down the left (no. 1) engine before arriving at the gate, parked

side of the aircraft. ... She heard the 'sound of something hit the propeller' and she saw the individual 'flip and land on the ground.'"

The injured employee had been hired about one month before the accident and had received one week of general training, followed by specific training that had included instructions to always "chock the main landing gear by approaching from the rear," the report said.

Another accident scenario involves hand-propping to start a small airplane's engine.

For example, an NTSB report cited the pilot's "inadequate start procedure" as the probable cause of a Nov. 25, 1998, accident in London, Kentucky,

much as 13 ft (four m) beyond the sides of the helicopter — and can be easily accessible. Rotating helicopter blades are especially dangerous to people outside the aircraft when the helicopter is being powered down and the centripetal force on the main-rotor blades is reduced, allowing them to droop closer to the ground. Because of their height, they are associated with head trauma more often than with any other type of injury.

A typical helicopter main rotor turns about 450 rpm, with tip speeds of as much as 500 mph (805 kph) — far exceeding the minimum force required to cause serious injury or death if they strike someone.



Paint bands on propellers and rotor blades become visible concentric circles when in motion, helping ground personnel identify and avoid their dangerous arcs.

For example, published reports described an accident in March 2006 in Nibong Tebal, Malaysia, in which an official of a housing development company was killed when he was struck on the head by a rotor blade of a Eurocopter AS 365 Dauphin. The accident occurred as the official walked away from the helicopter after checking to ensure that one of its doors was latched securely before what was to have been an aerial tour for several schoolchildren.⁵

Tail-rotor blades — designed to counteract the torque of the main rotor by generating a sideways force to control yaw and maintain the direction of flight — rotate up to seven times faster than the main-rotor blades, with blade-tip speeds of about 900 mph (1,448 kph; see “Unconventional Tail Rotors”). Tail-rotor blades have been cited in nearly three-quarters of U.S. helicopter rotor-blade accidents.

For example, an NTSB report cited a hospital security guard’s failure “to maintain clearance with the operating tail rotor” as the probable cause of a Jan. 22, 2001, accident at a hospital helipad in Quincy, Illinois, U.S., in which the security guard received serious injuries.⁶

The security guard — who was responsible for keeping unauthorized people away from the Bell 206L-1 LongRanger — walked into the tail rotor while crewmembers were preparing for departure on an emergency medical services flight. The security guard had attended a training session about one year before the accident that discussed “how to approach the aircraft in a safe manner while the rotors are in operation,” the report said.

Well-Known Hazard

A review of the NTSB accident database found that, from 1982 through early 2006, there were 166 accidents in

which people were struck by propellers or rotor blades; of these, 137 (83 percent) involved airplanes and 29 (17 percent) involved helicopters. The accidents were more than three times more frequent during the first five years of this period, when 56 accidents occurred, than during 2001–2005, when 16 accidents were recorded.⁷

The causes and circumstances of propeller and rotor-blade accidents have been recognized for many years. In the early 1970s, as part of a nationwide accident-prevention program, the U.S. Federal Aviation Administration (FAA) initiated an effort to educate pilots about the hazards.⁸

As part of that effort, in June 1975, FAA published the first of several advisory circulars that discussed fatalities and serious injuries caused by spinning propellers and rotor blades, and issued recommendations to prevent these accidents, which “with proper education and discipline ... could be reduced to zero.”⁹

The FAA effort was credited with helping to achieve a substantial decrease in propeller/rotor blade accidents. A 1993 analysis of NTSB reports on propeller/rotor blade accidents by the FAA Civil Aeromedical Institute (CAMI; now the Civil Aerospace Medical Institute) showed that the annual average number of accidents peaked in 1970–1974 at 25.6. The subsequent decline resulted in an annual average of 15.8 accidents from 1975–1979 — about 40 percent fewer than the previous half decade.¹⁰

That decline “seems attributable to several actions taken by the FAA in the mid-1970s,” the CAMI report said. “The methods included safety seminars, handouts, posters, a film depicting an actual accident resulting from improper hand-propping and the

Unconventional Tail Rotors

Conventional tail-rotor designs in helicopters have from two to five blades and rotate in the vertical plane. The length of the tail-rotor blades typically is in proportion to the length of the main-rotor blades; typically, a tail-rotor blade is about 4.0 ft (1.2 m) long, and the tail-rotor disc span is about 8.0 ft (2.5 m). The bottom edge of this span can be 5.0 ft to 6.0 ft (1.5 m to 1.8 m) above the ground.

Two alternative designs that significantly reduce the risk of injuries associated with tail-rotor blades are the fenestron and the NOTAR — or NO Tail Rotor.

The fenestron, patented by Aérospatiale and in use on helicopters manufactured by Eurocopter, resembles a conventional tail rotor in that both systems have spinning blades that generate an aerodynamic force to counteract the torque of the main-rotor blades. However, a fenestron's blades are mounted within a shroud,

or enclosure, that forms part of the tail fin of the helicopter. This also is known as a “fan tail” design. In addition, a fenestron has between eight blades and 13 blades, compared with conventional tail rotors, which seldom have more than four blades. Fenestron blades are smaller than conventional tail-rotor blades and rotate at faster speeds.

Because of the fenestron's enclosure within the shroud, its blades are far less likely to come in contact with people — or with trees, electric power lines and other obstructions.

The NOTAR design, in use on the more recent models of MD Helicopters, eliminates the tail-rotor apparatus and in its place uses jets of compressed air that are forced out of two slots on the right side of the tail boom. MD Helicopters says that the result is the creation of “a boundary-layer control called the Coanda effect. The result is that the tail boom becomes a ‘wing,’

flying in the downwash of the rotor system, producing up to 60 percent of the anti-torque required in a hover.”¹ The jets of air change the direction of the airflow in the tail boom to create an aerodynamic force that opposes the main-rotor torque.

Andy Logan, chief technology officer for MD Helicopters, said that by eliminating the tail rotor, the NOTAR system has eliminated the cause of more than 25 percent of helicopter accidents worldwide. He said that the system also has secondary benefits that are “subtle and many,” including improved access to confined spaces, an ability to operate closer to obstructions and quieter operations.

— CER

Note

1. MD Helicopters. *NOTAR Technology*. <www.mdhelicopters.com>.

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release of FAA advisory circulars on the hazard of propellers.”

Another notable decline occurred from 1985–1989, when the annual average was 7.2 accidents — down 48 percent from the annual average of 14 accidents in 1980–1984. The decrease resulted partly from the “steady improvement in general aviation accident statistics,” as well as from a decrease in the number of hours flown, the report said.

The CAMI report said that, of the 104 propeller/rotor blade accidents that occurred from 1980 through 1989, 81 accidents (78 percent) involved airplanes; 21 accidents (20 percent) involved helicopter rotor blades, including 15 accidents that involved tail-rotor blades; and two accidents (2 percent) involved seaplanes. Nearly half of the rotor-blade accidents were fatal.

The 104 accidents resulted in 106 deaths and injuries; of those killed and injured, 66 percent were passengers, 16 percent were ground crewmembers, 14 percent were pilots, and 3 percent were spectators. One-third of all deaths and injuries occurred during deplaning, 25 percent occurred as the victim was assisting the pilot, 18 percent occurred during hand-propping a propeller, and 14 percent occurred during enplaning.

Twenty-seven percent of the accidents occurred during dusk or darkness, “when ordinary propeller conspicuity, even at a well-lighted airport, would be considerably reduced,” the report said. About 44 percent of those accidents involved people providing assistance to pilots, 29 percent were deplaning accidents, and 13 percent were enplaning accidents.

A similar study of U.S. Army helicopter accident records found that 24 rotor-blade-strike injuries, half of which involved tail-rotor blades, occurred

from 1972 through 1991.¹¹ Eleven of the injuries (46 percent) resulted in fatalities, mostly from head trauma. Of the 24 people injured, half were crewmembers, seven (29 percent) were passengers, three (13 percent) were ground crewmembers, and two (eight percent) were bystanders. During the years included in the study, one rotor-blade-strike fatality occurred approximately every 1.7 years. When data were analyzed in five-year periods from 1972 through 1991, a downward trend in accident frequency was similar to the trend identified in the 1993 study of U.S. civil helicopter accident data.



Paint Schemes

For decades, manufacturers and operators have used various methods to help prevent injuries caused by rotor blades and propellers. One involves the use of different paint schemes to increase the conspicuity of rotating rotor blades and propellers. This strategy was suggested as early as 1954, when the U.S. Navy began using a black, red and white pattern on propeller blades; when the propeller is in motion, this pattern results in the visual effect of concentric circles.¹²

In the years that followed, blade conspicuity was studied repeatedly; researchers often reached different conclusions, and manufacturers used a

variety of paint schemes on propellers and rotor blades.

Today, for example, many airplanes and helicopters have stripes of high visibility paint on their propellers and rotor blades, and many helicopter tail rotors still have a black-and-white paint scheme — which was designated as “most conspicuous” in a 1978 report by CAMI.¹³ Among the most recent recommendations is one from Defence Research and Development Canada, which calls for two brightly colored stripes, discontinuous from one blade to the next, on each of the four main rotor blades of the CH-146 Griffon combat support helicopter. This configuration is designed to produce a circular flickering effect as the blades rotate.¹⁴

Among the factors that affect the conspicuity of propellers and rotor blades are color contrast between elements of the blade color scheme and color contrast between the blade color scheme and backgrounds. Brightness contrast between elements of the blade color scheme and brightness contrast between the blade color scheme and backgrounds also are considered, as are the patterns of colors on the blades, the rotational speed of the blades, and the size and number of blades.

Hartzell Propeller paints contrasting blade-tip markings on the forward surfaces of its propellers — and on both forward and aft surfaces of pusher-type propeller installations. The company encourages its customers — aircraft manufacturers and aircraft modifiers — to choose blade-tip stripes in contrasting colors, such as white tip stripes on a black blade, or red and black stripes on a white blade, said Richard Edinger, vice president for certification and flight safety at Hartzell.

“We have observed propellers (more commonly those in military use) where

one or more blades are painted with alternating stripes of black and white the full length of the blade, and the remaining blades are painted with the reverse arrangement,” Edinger said. “This gives a noticeable strobing effect, although the appearance would probably be very unappealing to many.”

Recommendations to aircraft owners and operators are that they maintain or adopt a paint scheme to enhance propeller/rotor blade conspicuity. However, an existing paint scheme should not be changed unless a specialist has determined that the new paint scheme will not interfere with pilot vision, induce flicker vertigo or result in an unbalanced blade condition.

Other engineering strategies also are recommended to aid in preventing deaths and injuries associated with propeller/rotor blade strikes.

For example, audible or visual warning signals sometimes are used to alert helicopter pilots if doors are opened while the engine(s) are being operated. This lets pilots know if passengers unexpectedly attempt to exit the helicopter.

Additional lighting of the rotor blades — with wing lights or tail boom lights aimed at the blades, for example — can increase conspicuity at dusk, in darkness or in other low-light conditions. Other solutions include blade markings that are visible only at idling speeds and flashing strobe lighting to direct attention to the tail-rotor blades.¹⁵

Safety Programs

Although engineering solutions are vital to accident prevention, aviation safety specialists also recommend well-designed and well-implemented safety programs that address human factors. Programs to reduce propeller/rotor-blade accidents should involve

pilots and other crewmembers, ground personnel, passengers and airport/heliport managers.

For example:

- Airport managers should provide safety barriers and related markings to ensure that unauthorized people do not loiter among parked aircraft;
- Operators should ensure that all personnel receive recurrent safety training in the risks of working around propellers and rotor blades. Warning signs displayed within aircraft cabins and in passenger pre-boarding areas should describe the risks presented by propellers and rotor blades and the enplaning and deplaning methods developed to minimize those risks;
- Airport personnel should direct passengers from terminal doors to their aircraft, or rope stanchions should be provided to designate appropriate walkways. Helicopter passengers should be told always to approach and depart the helicopter from the front — *never* from the rear; if a helicopter landing area is on or adjacent to a hill, passengers should not approach or depart the helicopter on the upslope side so that they avoid the area of lowest rotor clearance;
- Before starting an engine, flight crewmembers should ensure that all personnel are clear of all propellers or rotor blades. Only individuals with experience in hand-propping an airplane should perform the procedure; when they do, a person familiar

with the procedure should be at the controls;

- People who must walk beneath a helicopter’s main-rotor blades should crouch low well before approaching the blades. If they are suddenly blinded by dust or debris, they should stop moving and crouch lower; a better alternative is to sit and wait for help. They should not try to feel their way to or from the helicopter. No one should reach up for any object that might be blowing away or chase after the object;
- Whenever possible, engines should be shut down before enplaning or deplaning passengers. When engines must be kept operating, flight crewmembers should tell passengers — before they exit the aircraft — which path to follow to avoid propellers and rotor blades. A helicopter pilot should orient the helicopter with its tail rotor away from the passengers’ route to or from the helicopter; and,
- Pilots, maintenance personnel and others working in and around aircraft should behave at all times as though ignition switches are “on.” If they are carrying long tool rods or other equipment as they approach a helicopter, the equipment should be positioned horizontally to avoid possible contact with the main-rotor blades.

Aircraft manufacturers and operators have tried for years to prevent accidents in which people are struck by spinning propellers and rotor blades. Today, although these accidents are infrequent, they often are fatal.

Nevertheless, authorities say, with attention to blade conspicuity and safety programs, most of these accidents can be avoided. ●

Clarence E. Rash is a research physicist at the U.S. Army Aeromedical Research Laboratory (USAARL) in Fort Rucker, Alabama, U.S. He has more than 25 years of experience in Army aviation research and development and is the editor of Helmet-Mounted Display: Design Issues for Rotary Wing Aircraft, SPIE Press, 2000.

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