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Tiltrotor Offers A Choice

Although the first flight of the V-22 Osprey tiltrotor has been delayed, the author has had the opportunity to fly Bell-Boeing's simulator at Ft. Worth, Tex., U.S. Through his description of his simulator ride, it is apparent the tiltrotor will be a challenge for both fixed-wing and helicopter pilots.

by

Joe Mashman

Bell Helicopter Textron, Inc. and Boeing Helicopter Company joined forces to develop the V-22 Osprey tiltrotor aircraft, based upon the Bell Model 301/XV-15, a two-seat tiltrotor research aircraft.

The all-composite (epoxy/graphite laminate) V-22 is 57.25 feet long and has a 46.5 foot wingspan. Its obstruction-free cabin is 24 feet 2 inches long, 5 feet 11 inches wide and 6 feet high, and allows versatile configurations for personnel or cargo. Two Allison T406-AD-400 engines will deliver up to 6,150 shp to turn the two 38-foot diameter rotors. In airplane mode the V-22 will cruise at 275 knots with a 300-knot dash capability; helicopter mode will allow up to 100 knots in level flight. VTOL maximum gross weight is 47,000 pounds, but that increases to 60,500 pounds when the rotors are configured for a short take-off run of about 500 feet. Total JP-5 fuel capacity is 29,650 pounds, including the ferry tank configuration that allows 16,000 pounds of fuel in rigid tanks in the main cabin to enable an unrefueled range of 2,100 nm.

Maiden Flight is Expected Soon

The V-22 is scheduled to make its first flight early in 1989 after being rescheduled about four times. Originally, the maiden flight was to take place in June 1988. The U.S. Marine Corps is scheduled to receive the first production models in 1991. The U.S. Air Force, U.S. Navy and U.S. Army also are scheduled to receive variants of the aircraft.

Commercial applications also are being studied, and they range from an eight-seat executive version to a 75-seat short-haul airliner.

Flying the Tiltrotor Simulator

This pilot recently flew the Bell-Boeing engineering tiltrotor simulator, at Ft. Worth, Tex., U.S., and discovered the unique qualities of the tiltrotor aircraft.

The simulator was configured with the U.S. Navy V-22 Osprey control system and flight characteristics; the simulation called for 40,000 pounds maximum gross weight at sea level, standard conditions. The handling qualities of the aircraft were developed from the simulator, as well as inflight emergency procedures to determine their effects on handling characteristics under differing system failures. In order to better appreciate the aircraft's safety aspects, a pilot must first understand the control system and the various modes of flight, from VTOL mode to airplane mode.

Understanding the Basics of the Tiltrotor

Tiltrotor flight is made possible by power-lift and aerodynamic forces. The magnitude of the power lift, or thrust vector, compensates for wing lift lost as forward velocity is reduced. For this reason, the tiltrotor employs both conventional aircraft control surfaces (elevator, rudder, flaperon) and conventional tandem rotor configuration rotorcraft controls (differential collective, cyclic tilt, differential cyclic tilt).

However, the side-by-side rotor configured tiltrotor utilizes differential rotor control for different axes than the tandem rotor helicopter. For example, differential collective controls pitch in the tandem rotorcraft; in the tiltrotor, it controls roll. The tiltrotor also has a control for thrust vector tilt, allowing fuselage tilt to enable landing on steeper side slopes than possible with present-day helicopters.

A “fly-by-wire” system reshapes the pilot’s input to provide the desired aircraft control response; the aircraft response is precise and obedient, with no overshoot, and the pilot does not directly cope with adverse handling characteristics, such as trim changes, axis cross-coupling and effects of outside disturbance. The stick’s artificial control forces are adjustable.

Tiltrotor flight controls are laid out similar to those in a conventional airplane. In the V-22, the command pilot may fly from either seat. A stick is used to control pitch and roll, conventional pedals are used to control yaw, and a power lever, similar to a conventional airplane throttle, controls power amplitude.

The V-22 rotor speed in the VTOL mode is 397 rpm at 100 percent power, and 333 rpm at 84 percent power in the airplane mode. Proprotor speed is automatically regulated by the nacelle angle switch located on the thrust control lever grip. When the pilot commands “up nacelles” from the airplane mode, he also is commanding an increase in proprotor speed from 84 percent to 100 percent. When 100 percent speed is obtained, the nacelles move toward the VTOL mode as commanded.

Handling the Aircraft in VTOL Mode

Control in the VTOL mode is accomplished by rotor-generated forces. Pitch is determined by longitudinal cyclic pitch. Forward cyclic stick generates a nose-down attitude, and aft stick generates a nose-up attitude. If the aircraft is in hover, forward stick produces forward flight, and aft stick produces rearward flight. Roll control is determined by differential collective pitch.

Right lateral stick decreases thrust of the right rotor and increases thrust in the left rotor; the reverse is true for left lateral stick. In forward flight, this produces a banked turn; in a hover, it produces banked sideward flight. In addition to lateral stick for sideward flight, a lateral translation mode is selected by a small trim wheel located on the thrust lever grip. This control produces lateral cyclic tilt that results in sideward flight without bank. This is a very handy feature for crosswind landings, as well as landings on sloping terrain.

The power lever regulates the amplitude of the thrust vector. In the VTOL mode, it controls vertical climb and vertical descent; in the airplane mode, it increases and decreases speed. The nacelle angle switch controls the direction of the thrust vector from zero degrees in the airplane mode to 90 degrees in the VTOL mode. The nacelles can be rotated toward vertical as a means of decelerating in the airplane mode or they can be brought aft of vertical to 97.5 degrees, allowing rearward flight in a level attitude in the VTOL mode. Yaw control is provided by differential longitudinal cyclic tilt. Moving the right pedal forward and left pedal aft tilts the right rotor aft and the left rotor forward. In a hover, the aircraft rotates about a point midway between the rotors.

Tips for Takeoff

Take off in the tiltrotor VTOL mode is surprisingly easy, since the aircraft displays a high degree of stability and control dampening in pitch, roll and yaw. Roll and yaw dampening are better than found on conventional helicopters because of the inertia of the wing-tip-mounted engines. Hovering altitude control is very simple using the power lever, and the counter-rotating proprotors eliminate the need to use the directional foot pedals to maintain heading as power is increased or decreased.

Application of lateral stick in hover starts a predictable lateral acceleration. Opposite lateral control easily returns the aircraft to hover. A slight nudge on the foot pedals initiates a hover turn about the vertical axis with virtually no power adjustment needed. Movement forward and aft is done by fore and aft stick control as in a helicopter — lower the nose to accelerate and raise the nose to decelerate. A simpler procedure is to apply a touch of forward nacelle tilt to accelerate, a touch of aft nacelle tilt to decelerate.

It is not necessary to consult the cockpit nacelle indicator to find an exact nacelle angle. Nacelle tilt yields a predictable and immediate acceleration while maintaining a level fuselage pitch attitude. The effect is very controllable and forgiving; using nacelle tilt does not result in sudden sink or pitch up.

Changing From VTOL Mode to Airplane Mode

Various techniques have been developed to perform the conversion from VTOL hover to airplane mode, but I prefer the one used by Bell XV-15 pilots. From a hover, advance the power lever forward to the stop. (Torque rises promptly to 100 percent, with automatic limiting on torque as well as turbine outlet temperature.) Then push the nacelle tilt switch forward to obtain an immediate and strong level attitude acceleration. About two seconds later release the nacelle tilt switch at a 15-degree forward tilt, and allow air speed to rapidly build up to 60 KIAS, then reapply the nacelle switch and hold it.

Coming through a 45-degree nacelle angle, the aircraft pitches up 10 degrees, providing the climb angle of attack the wings require to take over lift duties. At this point, the aircraft responds to control movements as a conventional fixed-wing aircraft. Approximately 18 seconds after the start of takeoff, the nacelles reach full airplane mode at 105 KIAS. About 20 seconds after start, the aircraft passes through 160 KIAS in a 2,000 fpm climb.

Pressing once more on the nacelle switch commands a proprotor rpm reduction to the 83 percent cruise setting. During the nacelle conversion process, the auto flap function progressively raises the flaps from the 67-degree setting used in hover for rotor downwash alleviation, to the flaps up configuration in the airplane mode.

Preparing for Landing

Landing requires a power reduction on the downwind leg to stay below 200 KIAS (Vcon, the maximum speed at which reconversion to VTOL mode can be initiated).

Mid-point on the downwind leg, a touch on the nacelle switch (aft), restores rpm to 100 percent. While reducing power, the nacelles are moved further aft to a 60-degree angle and airspeed should be about 130 KIAS abeam the runway threshold. The aircraft still responds to flight controls as a conventional airplane.

The gear is lowered. Flap deployment automatically comes down to 40 degrees, resulting in a slight lowering of the nose. Air speed is reduced to 110 KIAS, while turning on base. Turning on final, the nacelles are moved further aft, as required, to gradually reduce speed, while adjusting power to stay on the desired glide path. The aircraft is brought to a hover in a VTOL mode to land.

A fixed-wing pilot with no prior helicopter experience will probably be required to obtain a helicopter rating to handle the entire envelope of the aircraft's helicopter capabilities. A helicopter pilot with fixed-wing experience should check out in a few hours, most of which can be done in a flight simulator.

Analyzing the Aircraft's Safety Features

The V-22 promises some well-designed safety features, which are better appreciated after the initial look at the aircraft.

- One-engine-out operation requires no trim change, and the operating engine automatically restores required power to both rotors by means of an interconnect drive shaft connecting both power-plants. With each engine on line, this drive shaft carries no load.

  If the shaft fails, the automated governors and fuel controls on each engine maintain required torque and rpm settings.

- An auxiliary nacelle tilt mechanism provides the necessary redundancy.

- The control system is triple redundant and separated, utilizing a full authority, digital fly-by-wire system. The primary flight control system is designed to surpass a one-in-10,000,000 flight hours failure rate. The automatic stabilization system is designed to a somewhat higher failure rate, since the aircraft can be flown on primary alone. The redundant systems are self-monitoring, and cross-monitor as well.

- Electrical systems are triple redundant and hydraulic systems are dual redundant.

- Transmissions and gear boxes are designed for one-hour-run-dry emergency conditions at high power.

- In the event of dual engine failure, both engines automatically decouple from the transmissions, allowing the proprotors to windmill. Air speed drops off, but the pilot can keep the aircraft in the airplane mode and continue to glide at an approximate 8:1 glide ratio. The pilot can convert the nacelles to the helicopter mode and steepen the approach to a 3:1 slope, followed by a slow 40 to 60 KIAS roll-on landing. This type of emergency procedure has been fully investigated and demonstrated in the XV-15 demonstrator aircraft.

To minimize the possibility of system failures, a state-of-the-art diagnostic system is installed on the aircraft. The engines, transmissions and drive shafts have elements that monitor temperatures, pressures, vibration levels, power levels and torque. Potential problems can be identified and corrective actions initiated before a system or component fails.

In addition to providing a potential increase in safety, the on-board monitoring has a meaningful economic benefit. Time lost for inspections, overhauls and, above all, unscheduled maintenance downtime, a long-time enigma for current helicopters, is reduced.

The new generation of tiltrotor aircraft has the potential of equaling, and surpassing, the safety and passenger acceptance of current commercial aircraft.♦

About the Author

Joe Mashman (ATP/CFR, commercial examiner Rotary/Fixed) is a pioneer in the rotorcraft world. After joining Bell as a test pilot in 1943, he made the change to rotary wing in 1945 after the company constructed its first experimental helicopter.

Before retiring in 1983 as vice president of special projects, Mashman had accumulated approximately 21,000 flight hours, 16,000 of them in rotorcraft. His rotary time includes experience in helicopters manufactured by several countries, including the Soviet Union. He has flown the heads-of-state of several nations and U.S. cabinet members. He served as personal pilot and special advisor to U.S. President Lyndon B. Johnson.

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