New rotary wing technologies

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Rotary wing technology like most aerospace technologies has evolved slowly since the end of the Cold War. Without the imperative of a well identified threat there has been little political or bureaucratic interest in maintaining the technological advantage the West held over all nations in 1991.

At the end of the Cold War, the United States held a commanding advantage in most conventional rotary wing areas, with the Europeans lagging but closely behind, and the Soviets behind in all areas other than heavy lift helicopters.

At that time the US had two new programs in development, the V-22 Osprey, which was to herald a generation of new tiltrotor technology designs, and the RAH-66 Comanche Scout helicopter which was to have been the vehicle for new rotor technologies, and a very low signature or 'stealth' design.

Two decades later the Comanche is 'dead' and the V-22, after a very painful and protracted development cycle, is only now achieving credible operational maturity. Most of the military helicopter types remaining in production in the US are derivatives or variants of Cold War era designs. Europe is faring better, as it has a generation of new rotary wing designs now in production, using composite structural materials extensively, but these vehicles are in aerodynamic and propulsion terms just as conventional as their trans-atlantic siblings. Much the same can be said of the latest designs in Asia.

In terms of mainstream production helicopter designs it would be fair to describe the area as largely stagnant. Most current helicopter production is intended to extend or directly replace Cold War fleets with like designs, at best with incremental improvements in performance parameters like payload range, life cycle cost or ballistic tolerance, and with more sophisticated digital avionics replacing the conventional cockpits of Cold War era designs.

Historically, rotary wing development followed two key lines of advance.

The first has been efficiency, manifested in range-payload performance and fuel burn in cruise and hover. This imperative has produced incremental improvements in engine efficiency, the introduction of composite materials to reduce empty weight, and incremental advances in rotor blade aerodynamics to reduce drag and improve lift.

The second line of advance has been the pursuit of higher cruise speeds. This in part reflects commercial and military needs for shorter transit times carrying operational payloads, and in part reflects the military imperative of minimising exposure to modern air defence weapons, which are becoming increasingly potent as digital technologies displace legacy analogue systems.

Sikorsky X2.

The principal impediment to faster helicopters has been the retreating blade stall effect, inherent in single rotor designs, and often the reason why fast helicopters are also equipped with short span wings.

Numerous ideas have been prototyped in the past to make rotary wing aircraft faster, to date the only one design has resulted in an operational product, but the Bell/Boeing V-22 Osprey tiltrotor is the subject of ongoing controversy resulting from fatal crashes.

Tiltrotor Technology

The tiltrotor idea was explored by Bell decades before the highly successful DARPA/NASA XV-15 demonstrator was built. The basic idea behind the tiltrotor is simple: install tilting nacelles which mount prop-rotors, used as rotors to hover and props to cruise. However, the implementation results in a complex design, with crosslinked drive shafts and controls to ensure that loss of one wingtip engine or gearbox does not result in loss of control.

The XV-15 demonstrator was a success story, so much so that the JVX program was launched without a technology demonstrator to determine how difficult it might be to scale the vehicle up to the size of the Boeing-Vertol CH-46 Sea Knight,

The cancelled RAH-66 Comanche scout helicopter was to have been a high technology replacement for the legacy scout fleet. It was cancelled.

The Bell XV-15 Tiltrotor demonstrator was highly successful, and the basis of the current V-22 Osprey and BA.609.

The Agusta/Bell BA.609 is the first tiltrotor design developed for civilian users. It is intended for high revenue markets such as executive transport or oil/gas industry offshore operations.

V-22 Osprey.

which the JVX was to replace. Late 1980s product literature was literally exuberant in extolling the potential of the JVX to cover a wide spectrum of roles, displacing large helicopters and smaller turboprops.

The idea of a 250 KTAS cruise speed vehicle, with range-payload performance competitive against most twin engine turboprops and a helicopter like vertical take-off and recovery, is hard to argue against. The US Marine Corps was especially enamoured with the concept, as it increased almost twofold the rate at which a beachhead could be resupplied and reinforced. This would allow amphibious ships to stay over the horizon, minimising launch opportunities for coastal anti-ship missile batteries.

Unfortunately, scaling the tiny XV-15 up to the V-22 proved to be much more painful than expected, and the result was a protracted and very expensive development program, followed by an accident prone early deployment phase. As a result the V-22 remains an expensive low volume product currently used in the MV-22 configuration by the USMC, and in CV-22 Combat SAR/SOF configuration by the US Air Force. Opinion in the technical and flying community remains divided over this design. What is clear though is that regardless of the virtues or failings of the design much more effort should have been invested in risk reduction earlier in the development program.

The more recent offspring of the XV-15 is the new Bell/Agusta BA.609 tiltrotor in development to provide a 6 to 9 passenger 250 KTAS transport capability for the niche markets such as executive transport, offshore oil/gas platform resupply and other like civilian roles in which the fast transit speed and 750 nautical mile range performance would be especially valuable.

Coaxial Rotors and Propulsors

Two other technologies with long gestation periods are experiencing a revival in current technology demonstration programs. The first of these is the propulsor, a tail mounted propeller or ducted fan intended to provide forward thrust in cruise flight, and the second of these is the coaxial rotor, intended to overcome the retreating blade stall problem.

Both of these technologies were demonstrated decades ago but did not proceed to development and production.

The propulsor idea was first applied in a high speed helicopter design during the development of the Lockheed AH-56 Cheyenne attack helicopter during the late 1960s. The Cheyenne was a purpose built attack helicopter and entirely new design, unlike the AH-1, derived from the UH-1 and suffering its key performance and handling limitations.

While the Cheyenne employed a conventional four blade main rotor, its four bladed tail rotor was mounted on the tip of the port horizontal tail, and a large three bladed pusher prop was fitted to the aft fuselage. A large low fuselage wing was fitted. The Cheyenne was powered by a single 3,900 SHP T64 engine, much larger in power rating than any previous helicopter of this size. The intent was to produce a design capable of exceeding 200 KT in level flight.

The Cheyenne ran into difficulties with its control system design, weight, performance and cost. The ambitious production program was cancelled in 1969 but the development funding was maintained until 1972. Ultimately, the niche occupied by this design was filled by the much slower AH-64 Apache, designed for a very different style of combat.

Piasecki / PiAC X-49A Speedhawk or Vectored Thrust Ducted Propeller (VTDP) demonstrator.

The Sikorsky S-69 / XH-59 Advancing Blade Concept demonstrator was flown for over a decade to prove coaxial rotor and jet propulsor technology. It remains one of the fastest rotary wing designs ever built.

What the Cheyenne did prove convincingly was that the combination of wings and tail propulsor permitted sustained speeds of around 200 KTAS, almost twice that of most conventional helicopters. Tail propulsor technology in two different forms is part of two current US technology demonstration programs, the Piasecki / PiAC X-49A Speedhawk or Vectored Thrust Ducted Propeller (VTDP) demonstrator, and the Sikorsky X2 technology demonstrator.

Piasecki, a name well known to students of rotary wing history, is a small technology company based in Pennsylvania. The X-49A demonstrator was funded by the US Army under the SBIR program and involved rebuilding an SH-60 Seahawk airframe, which has been converted into a compound helicopter with a large flap equipped dihedralled wing and a large tail mounted ducted prop propulsor system. The latter is used to provide yaw control and torque cancellation in hover and yaw control and forward thrust in cruise flight.

The X-49 flew in 2007 and all initial contract goals were met by 2009, followed by a US Army funded Advanced Technology Demonstration (ATD) program.

Piasecki cites the following advantages of the compound wing/propulsor design: “In combination with a lifting wing, this technology unloads the rotor allowing the helicopter to fly 50 per cent faster, twice as far, is more manoeuvrable and reduces vibration and fatigue loads, improving reliability and reducing life cycle costs.”

Concurrently, Sikorsky has been working on the far more ambitious X2 coaxial rotor/pusher design. Coaxial rotor technology is not new, and Russia’s Kamov has been building helicopters with this technology since the early 1960s. Sikorsky is also not a newcomer to this technology, having developed the Sikorsky S-69/XH-59 Advancing Blade Concept (ABC) demonstrator in 1972. This design used a rigid blade coaxial rotor design, and a pair of side mounted J60 turbojets to provide additional thrust. The demonstration ran until 1982.

The X2 demonstrator aims to prove a number of technologies including high lift/drag rigid rotor blades, low drag rotor hub fairings, a six-bladed pusher prop propulsor, an Active Vibration Control system, and an integrated Fly By Wire control system with authority over rotor speed, engine and propulsor. Not unlike the S-69/XH-59 ABC demonstrator, the X2 is intended to achieve fixed wing class cruise speeds, with the hover efficiency of a conventional helicopter.

The original S-69/XH-59 ABC demonstrator was known to be prone to vibration and would have faced genuine challenges with the analogue control system technology of that era. Clearly the intent with the X2 is to prove that advanced digital technology can overcome earlier problems.

Sikorsky X2 demonstrator

Conclusion

With the Western world equipped with a large fleet of largely obsolescent rotary wing aircraft the immediate prospects for a revival in US rotary wing technology development and production are not particularly good.

The two most visible current programs, the X2 and X-49, are attempts to capitalise on earlier US research and employ modern digital technology to overcome control and vibration problems that were beyond the analogue technology of the 1970s and made period advances impossible to implement. Even if both the X2 and X-49 lead to robust technologies for production designs, designs which are desperately needed to replace out-of-life legacy fleets, it is an open question whether the procurement bureaucracy will be capable of successfully managing such programs to production and completion.

The sad state of advanced research and development in rotary wing aircraft, especially in the US, is a direct consequence of two decades of neglect, a problem not unique to the rotary wing world. Maintaining the ability to develop viable products requires ongoing development projects to maintain and train the personnel who will develop future products. Destroy that capability and it may be impossible to restore.

The cancelled Lockheed AH-56 Cheyenne has earned cult status since its cancellation in 1972. It was at that time the fastest combat helicopter design built in the US. It employed a pusher prop as a propulsor, and wing to overcome retreating blade stall, making it a compound helicopter.