Reenergizing rotorcraft R&D

Marat Tishchenko is hunkered down over his latest creation, a Frisbee-sized miniature helicopter he has built from scratch in a little over six weeks. Despite a few aerospace graduate students milling about, the University of Maryland lab around him is as hushed as a library. This reflects both intense concentration on the rotorcraft technology projects under way, and a reverence for their tall, thin 73-year-old Russian teacher and advisor.

From Moscow to Maryland

When it comes to designing and building helicopters, Tishchenko has pretty much seen and done it all. After becoming hooked on vertical flight at age 17, he pursued engineering at the Moscow Aviation Institute, graduating in 1956 with the qualification of "engineer-mechanic of helicopter construction," according to his resume. He immediately went to work for Michael Leontievich Mil at the Soviet Union's Helicopter Design Bureau, remaining there until 1991.

During that time, Tishchenko says, he "participated" as an engineer in creating 75-80% of all the Soviet Union's helicopters, including the world's favorite heavy lifter, the Mi-26, the beastly Mi-12, and dozens of others.

Judging by his position as chief designer and head of the design bureau from 1970 until his retirement in 1991, "participation" is either a modest assessment of Tishchenko's role, or a word that loses something in translation. Under his watch, the plant introduced or modified 36 military and civilian helicopters.

How he came to begin sharing his life's work with aerospace engineering graduate students in Maryland is quite unremarkable: As president of the Russian Helicopter Society, Tishchenko was speaking at an American Helicopter Society (AHS) forum in the U.S. in 1997. There he was approached by Inderjit Chopra, a helicopter dynamics expert and director of the Alfred Gessow Rotorcraft Center at the University of Maryland in College Park, designated as a NASA/Army rotary wing Center of Excellence.

Chopra approached him and asked, "Do you agree to come to our university?" recalls Tishchenko, who replied, "We can try to do it."

Tishchenko came to Maryland for four months the next year, bringing with him his Russian-made computer design code and experience. These were brought into the aerospace department's plan to help graduate students prepare for an annual vehicle design competition held by the AHS. From a broader perspective, the department also wanted some of his wisdom to rub off on its graduate students and ultimately pump new life into a faltering U.S. rotorcraft R&D scene.

The students won the graduate competition in 1998 with a proposal for a 12-seat civil vertical takeoff and landing (VTOL) rotorcraft capable of growing to 19 seats. The same thing happened the following year—Tishchenko came back, and the graduate students won the AHS competition for a quick-build four-to-six-seat VTOL aircraft. They won again in 2000, 2001, and 2002. In 2003, Tishchenko could not get approval to enter the country; the team won nonetheless.

Mara Tishchenko's miniature helicopter will serve as the baseline for the university's MAV work.

Staying competitive as budgets fall

AHS-type design competitions and expert advice from industry veterans are becoming increasingly critical as incubators of technology. This is especially true as the U.S. attempts to compete with a research-healthy European rotorcraft industry and as homeland resources dwindle: Rotorcraft budgets have declined at NASA, and other production priorities are consuming engineering staff at manufacturers.

This quandary is spawning a transition on campuses from a no-strings-attached collegiate mindset to an industry-as-customer culture. This means that departments sometimes have to agree not to publish certain competition-sensitive findings in manufacturer-sponsored research in order to preserve the funding stream. "In the older days, universities were purists," says Chopra. "That's changing now—people are becoming realists. We work with industry and try to safeguard their interests."

The larger problem for government and industry is finding the manpower and dollars to answer some of the fundamental questions about helicopter dynamics. Because these answers have so far remained elusive, today's predictive models can be incorrect by a factor of 10 or more. This has forced rotorcraft engineers to overdesign vehicles by making excessively conservative assumptions on blade loads and noise. Chopra says it is not uncommon to waste 10% of the useful load in vibration suppression devices for the cabin alone.

"We extrapolate to understand the behavior," he says, "and hope there will not be any surprises."

Some new technologies are making their way to the market in incremental doses. But the lack of basic research makes for longer development times and increased expenses due to trial and error design and suboptimal performance.

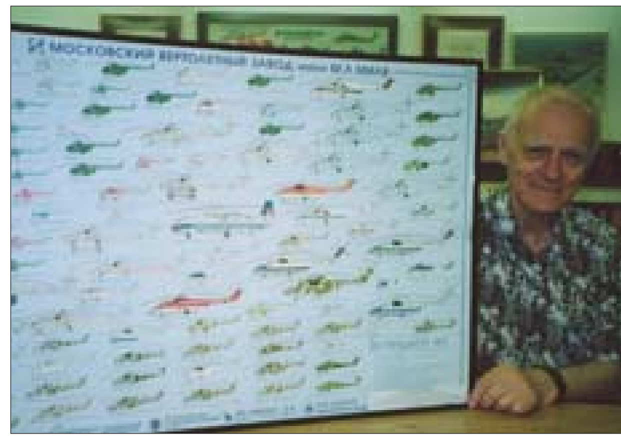
Complexity and cost

The fact that experts are not better able to predict noise and vibration characteristics in the rotorcraft design phase in this day and age reflects the complexity of the problem: The mechanics of a spinning rotor in a moving air stream can involve transonic flow on the advancing blade tips, dynamic stall and reversed flow on the retreating side of the disk, highly yawed flows on both sides of the disk, blade-vortex interactions, and mechanical coupling between the rotor, transmission, and airframe.

This situation also reflects how the national priority placed on helicopter research has faltered in light of diminishing budgets at NASA, previously the home of such efforts.

Rhett Flater is executive director and legal counsel for AHS. He says that DOD's anticipated need in 2015 for a very-heavy-lift VTOL vehicle with a 20-24-ton payload, 1,000-km range, 30% reduction in empty weight, and reduced vibration environment should be a wakeup call for technology investment.

Asked by the DOD what is needed to achieve those goals, AHS answered: A $2-billion investment in technology—$500 million a year for four years. "They were not happy with our response," says Flater. "They want to have a capability by 2015," he adds. "We said we probably can't develop it until 2020 because of a lack of basic research."



Tischenko worked on 75-80% of all Soviet helicopters through 1991.

A similar alarm was sounded recently on the civil side. Flater says the FAA just completed a congressionally mandated report investigating the funding needed to realize an advanced technology helicopter with 80% reduction in takeoff and landing noise, a factor of 10 reduction in vibration, a 30% reduction in empty weight, an accident rate reduced to that of commercial airlines, and operations in zero ceiling/visibility, all in a 10-year timeframe.

Again, the figure was not low. According to Flater, the FAA found that a $3.4-billion investment in technology would be needed, with the first three years allotted to "foundational research" and to basic prototyping and testing, and the remaining four to seven years to complex testing and validation of two prototype aircraft.

In either case, the numbers are far higher than today's technology investment, which comes largely from a four-decades-old 50/50 cost-sharing agreement between the Army and NASA to fund efforts like Chopra's.

Until 2002, NASA and the Army had each contributed what amounted to $60 million a year, with major helicopter manufacturers together providing a similar amount. In its 2002 budget request, however, NASA zeroed the contribution. Flater says AHS and other organizations were able to get the funding restored, though at reduced levels. Currently NASA and the Army are committed to minimum annual investments of $15 million each through 2008.

"NASA effectively eliminated its rotorcraft R&D efforts beginning in 2002," says Michael C. Romanowski, assistant vice president for civil aviation at the Aerospace Industries Association. "The Europeans are actively pursuing the goal they put forward in Vision 2020 to become the world's leader in all aspects of civil aviation—and they've backed this up with significant support for aeronautics R&D and other assistance.

"The effects of their efforts are shown by the increasing number of international rotorcraft competitions won by European rotorcraft manufacturers."

Regarding how that reduced NASA money is best spent, Flater says the goals are to reduce the empty weight and to create lighter, stronger structures, fly-by-wire and fly-by-light control systems, and advanced rotor technologies. The latter would include bearingless rotors and individual blade control with smart flaps—areas where the Europeans are leading the charge.

Chopra and others say the NH-90, made in the 1990s by the consortium of Agusta, Eurocopter, and Fokker, is the most advanced helicopter to date. It features a titanium hub with elastomeric bearings, four composite blades, an automatic monitoring and diagnostic system, and fly-by-wire controls, rivaling the Boeing/Sikorsky Comanche reconnaissance/attack helicopter program, which was canceled in February. The Comanche, which featured a five-bladed composite bearingless rotor and a triple-redundant fly-by-wire control system, was designed in part with analytical tools developed at

Maryland. But even with its advances, it still represents 1980s technology, unlike the NH-90.

Goals and innovations

Priorities at Maryland mirror Flater's wish list. They include funding for technologies to help today's fleet as well as some far-flung but analytically sound ideas for the longer term. Chopra has high aspirations for the overall impact on future helicopters: 60% reduction in vibration; 85% better aeromechanics prediction (predicting vibration from models); 24% increase in maximum rotor blade loading; 45% lower costs; 50% less perceived noise; and 50% reduction in development cycle time through next-generation design tools.

Maryland's rotorcraft team has an annual research budget of nearly $5 million. About 20% of this is from major helicopter manufacturers and the other 80% from government sources. It also funds 72 graduate students, 10 faculty, 10 research scientists, and visiting professors.

The team is perhaps best known for its "aeromechanics" expertise, including the "smart rotor" active vibration-reduction system that Boeing successfully whirl-tested in May on an MD 900 Explorer five-bladed rotor. Researchers are targeting improvements to the main rotor because it is the primary contributor of vibration and unwanted forces to the fuselage, causing more frequent inspections, higher maintenance costs for short-lived components, and an uncomfortable ride.

To reduce vibration, smart rotor technologies use trailing-edge flaps with "smart actuators" or active blade-twisting with embedded piezoceramic actuators.

The basic idea is to sample numerous lightweight surface-mounted or embedded sensors at various locations along the blade and in the cabin, run the data through a control system, and modify the local shape of the airfoil with surface-mounted or embedded actuators on the blade, canceling out vibration. For rotor-tracking tab adjustments, researchers are experimenting with active shaped-memory alloys; slow-reacting devices can trim the rotor with the application of voltage.

The MD 900 Explorer smart rotor system design was conceived by MIT (Maryland had a competing design), but all of the actuator development was done at Maryland, says Chopra. During the whirl testing of the rotor at Boeing Mesa's test facility in Arizona, Boeing reported an 80% reduction in vibration levels, though Chopra says DARPA "didn't show much excitement" about the results.

Eye on Europe

The smart rotor advances to some extent mimic the priorities of the European Union. Eurocopter last year announced a multipronged approach to new technology for its helicopters, including reduced development times via enhanced modeling tools and use of CFD in lieu of wind tunnel testing; lower maintenance costs and lighter materials through composites and bearingless main rotors; reduced external and internal noise and vibration via active rotor control; and pursuit of all-weather operations.

While U.S. manufacturers are incrementally upgrading today's designs with similar technologies, the rate of infusion is less aggressive. Technology incubators such as Maryland, however, are continuing to push the envelope as far as funding will allow. In addition to working directly with industry and writing technical papers, their most significant contribution is a freshly trained engineer. "The best way to get technology to them is our graduate students," Chopra says. "They take their ideas with them."

Thanks to Tishchenko, those ideas should have a rich backdrop from five decades of design, construction, and testing experience in a culture that prized function over form. His life may also help students to consider a road less traveled—holding on to engineering skills despite the pressure to move up and out after a successful project.

Chopra says it was difficult to find an advisor with Tishchenko's credentials in the U.S., meaning someone who had remained well versed in the design process through an entire career in industry. "Here, if you're good," he says, "you're promoted to management."

Experience from massive to micro

At 73, Tishchenko has to wear two pairs of glasses—one perched in front of the other—to see the fine details of his handmade piston-powered micro air vehicle (MAV), but he certainly has not forgotten how to make a helicopter, no matter its size. MAVs are Maryland's latest venture into futuristic helicopter technologies: Despite the missing ingredients in prediction models for full-scale vehicles, the military is sponsoring the development of miniature craft with a maximum dimension of 6 in. in any axis, a gross takeoff weight of 100 g, loiter time of 60 min, and payload capacity of 20 g.

Chopra says Tishchenko's sculpted masterpiece will be used as the baseline platform for all the school's future MAV work, which should be substantial given that the Army is funding the program through 2009 at $1 million a year.

The results of this year's AHS competition to design a mountain rescue helicopter have not yet been announced, but Tishchenko and Maryland are already excited about next year's contest: The proposal calls for a heavy-lift vertical takeoff and landing aircraft capable of hauling 20 tons of military payloads from a ship to an in-theater destination 1,000 n.mi. away—strikingly similar to Flater's military heavy-lift requirement.

Tishchenko has some experience in the sector, to say the least: His Mi-26 is currently the world's leader for heavy lift. At 20 tons, its payload is four tons more than the nearest competitor, the CH-53E, but only half as much as Tishchenko's ultimate claim to payload fame.

In 1967, just after completing his dissertation, Tishchenko was promoted to deputy chief designer at Mil. There he had the chance to put theory into practice on what would become the world's largest rotorcraft, the Mi-12. The aircraft was originally designed to carry a mobile missile transporter to a final destination after interim delivery by an Antonov An-22 transport aircraft. Mil eventually built two of the ungainly 40-metric-ton payload VTOL aircraft, whose maximum takeoff weight was 105 metric tons. But the aircraft never went into production. "When testing got to the end, there was no missile," he says.

The MAV, though petite by comparison, will surely take a place of equal prominence in Tishchenko's personal design hall of fame: When asked which creation he is most proud of, he smiles and repeats what his mother once said when someone asked which of her two sons she loved the most: "The pain is the same."

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