Adaptive Control Surfaces for Helicopter Rotor Blades

Shape morphing with Compliant Systems

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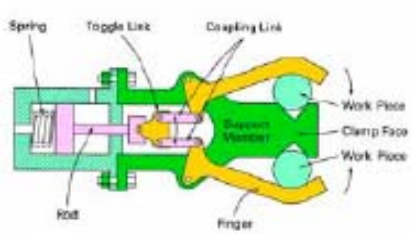
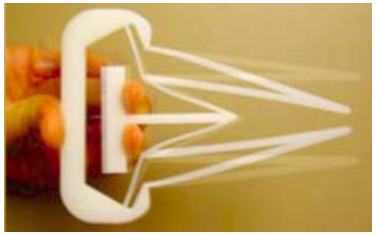
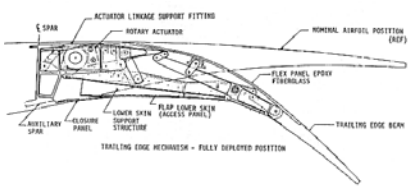
Bio-inspired Compliant Design

exploits elasticity of the materials to transmit forces/motion.





Traditional Rigid-link design vs. compliant design



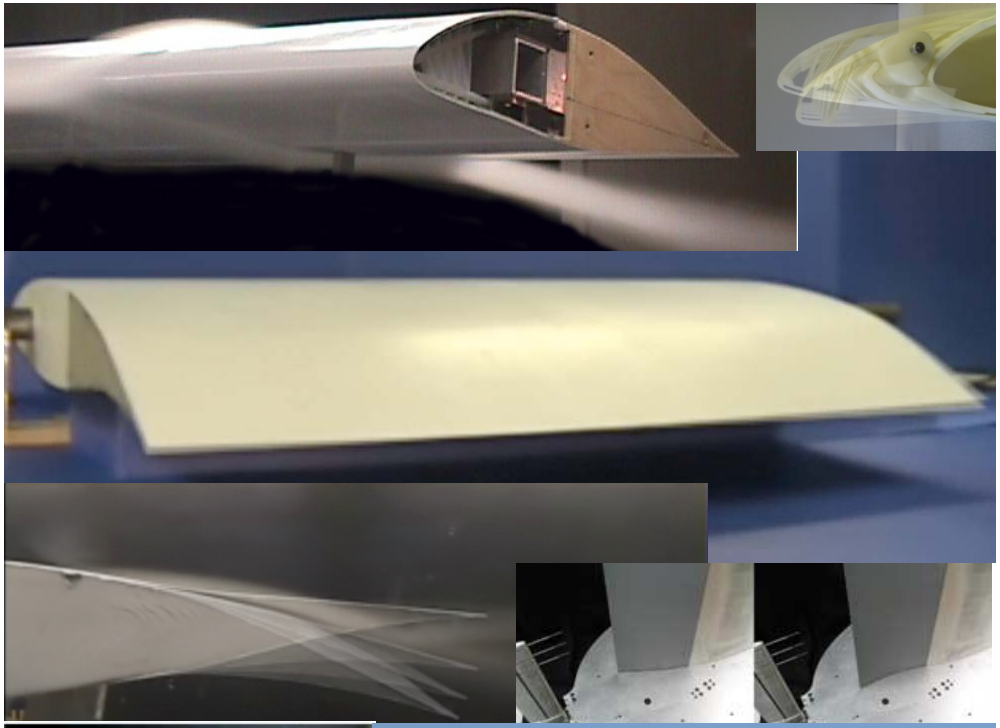
AFRI's Mission Adaptive Wing vs. FlexSys lightweight design

Benefits
-Monolithic; no-assembly
-No joints, no-wear
-Excellent Reliability
-High precision
-Simple construction
-lightweight

Distributed Compliance

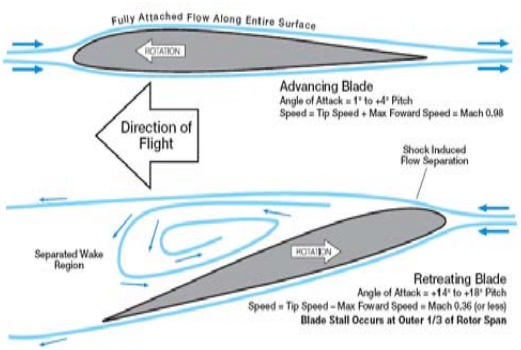
Strain energy uniformly distributed; no flexural hinges

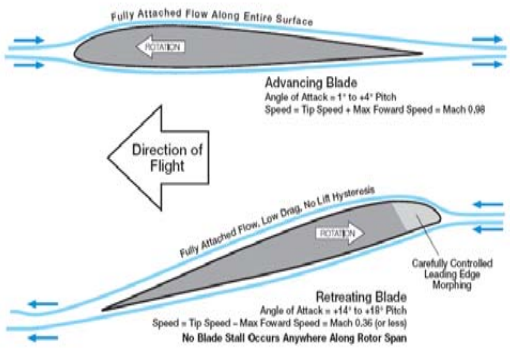
Mission Adaptive Compliant Wing



Material; Aluminum; +/- 10 deg.
Composites -10 to +40 deg deflection

Variable Geometry Helicopter Leading Edge

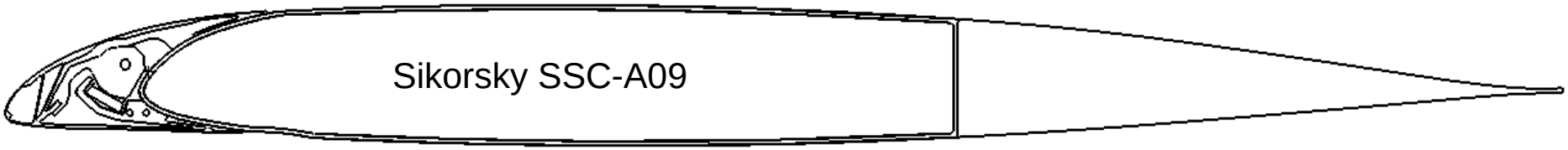




Significant improvements in forward speed and payload

Power and Weight

- Actuator - a linear electromagnetic motor
  - 2 x 3 x 15 inches; 15.5lbs
- Peak power consumed (under loads at 7 Hz) to actuate 7 foot flap is 885 Watts or 126 Watts/ft.
- Weight of the complaint system is 13.8 lbs for a 7-foot span or 2lb/ft.
- Weight of the linear electromagnetic actuator is 16 lbs.
- Total weight 30lbs or 4.3 lbs/ft.



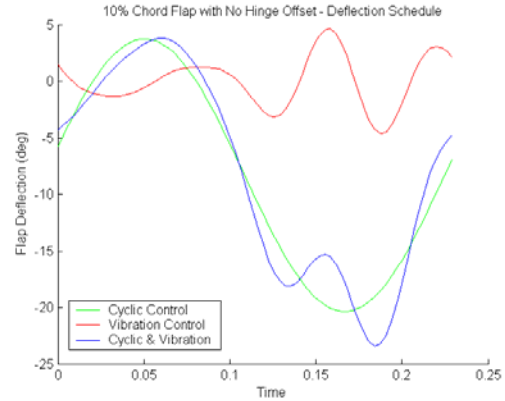
- 0 to 10 Degree Camber Change
- Match aero-optimized shapes precisely (99% accurate)
- 6 Hz actuation speed
- Survive 220 million cycles (~4500 hours with Factor of Safety =2)
- 1000 G lateral load at blade tip
- Pressure loads computed by RHRC
- Push D-spar rearward 8.5% (from tip) to clear space for compliant structure and actuation
- Flap stiffness > min stiffness to avoid aero elastic divergence
- No holes drilled in the D-spar

Material: Titanium;
See Video and Hardware demonstration

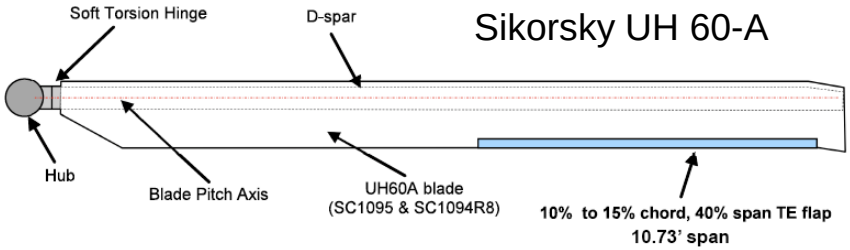
FlexRotor - Adaptive Complaint Trailing Edge

- Collective and cyclic control
- Vibration reduction

Performance and Reliability
Lower drag on advancing blade, higher lift and delay dynamic stall on retreating blade; Improved hover performance; Eliminate Swash plate; Reduce vibration



Wind tunnel model: Span 36” Chord 20” 10%flap



Compliant flap requires <u>20% less power</u> than a hinged flap.

See Hardware demonstration

Design Highlights: Seamless upper and lower surfaces; Material-Composite; -23.5^0 to $+4^0$ at 1/rev (5Hz) and -4^0 to $+4^0$ at 3/rev (15 Hz). Designed to withstand air loads (max Q – 950psf and 250psf) & 581 Gs inertial loads; Significant improvement in performance and vibration reduction.

FlexRotor - Mission Adaptive Compliant Rotor

FlexSys has a proven record of demonstrating lightweight, low power Mission Adaptive Control Surfaces for aircraft.

Pioneers in Compliant Systems technology.

Compliant systems enable, seamless control surfaces that are reliable, strong, and lightweight.

Proprietary design method works with standard materials (composites, titanium etc.) and a variety of actuator types.

FlexSys has the capability to design and fabricate a flight-worthy Mission Adaptive Control Surfaces such as variable geometry leading edge and trailing edge. Collaboration with an OEM needed for vehicle integration.