

Adaptive Rotor Development



TECHNO-SCIENCES DARPA Mission Adaptive Rotor Industry Day

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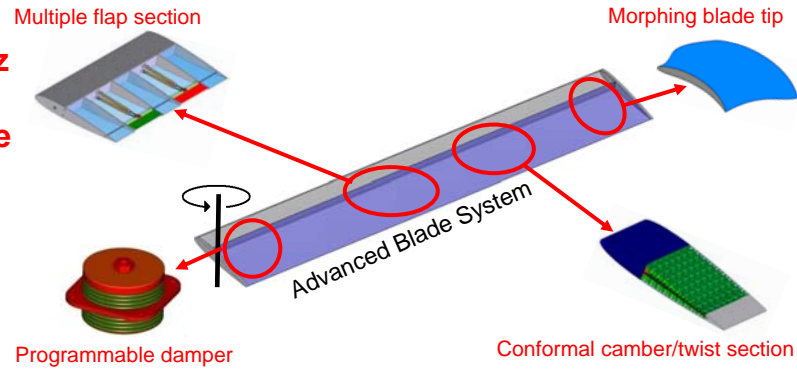
An opportunity exists for a new paradigm in advanced rotorcraft systems

Feasibility of enabling technologies has been demonstrated

- High authority flap actuation: ± 3 to ± 10 deg to 70 Hz
- Substantial damping augmentation: 50% to 100%
- Broad-scale morphing capability: 100% area change

Combining enabling technologies will lead to revolutionary advances in rotorcraft performance

- Swashplateless rotor
- Vibration and noise control capabilities
- Real-time adjustable rotor damping properties



Trailing-Edge Flap Actuation

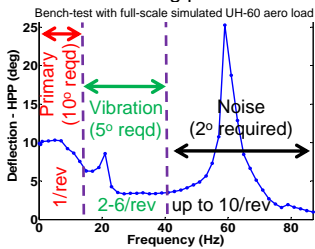
Pneumatic Artificial Muscles (PAMs)

- Improve flight control \rightarrow eliminate swashplate
- Reduce vibration \rightarrow increase life cycle
- Appropriate for full-scale (F~400 lb; x~30%)
- Low weight penalty (< 0.5 lb)
- High specific work (~500 in-lb/lb)
- Low operation pressure (< 100 psi)
- Proper bandwidth (1 – 50 Hz)
- High fatigue life (> 120M cycles)
- Minimum moving parts



TSi PAMs show promise for full-scale rotorcraft applications

- Full-scale UH-60 simulated aero load (Mach 0.56)
 - Primary flight control: ± 10 deg up to 10 Hz
 - Vibration control: ± 3.5 deg up to 35 Hz
 - Noise control: ± 1 to ± 3.5 deg up to 80 Hz
- Full-scale Bell 407 simulated aero & 80% CF loads
 - ± 8 deg up to 40 Hz at 660 g's
- Full-scale Bell 407 simulated aero load (Mach 0.56)
 - Primary flight control: ± 18 deg up to 10 Hz
 - Vibration control: ± 8 deg up to 35 Hz



Programmable Damping

Magneto-Rheological (MR) Fluids

LORD

MR dampers have numerous benefits

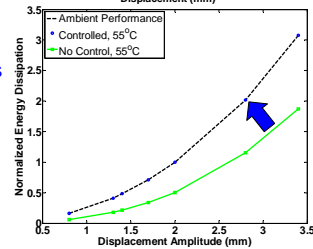
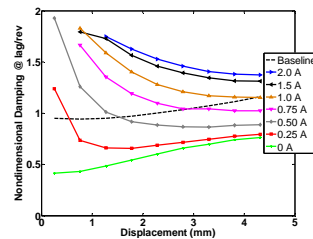
- No moving parts
- Fail-safe operation with no power
- Retro-fit capable for ease of integration

Designed, retro-fit, & tested MR control valves in Bell 430 lag damper

- Achieved 50% to 100% controllable damping
- Tested at lag/rev, 1/rev, & dual frequency

Temperature and amplitude compensation

- Tracked reference damping profile
- Restored temperature-dependent damping loss
- Implemented open-loop and closed-loop controls

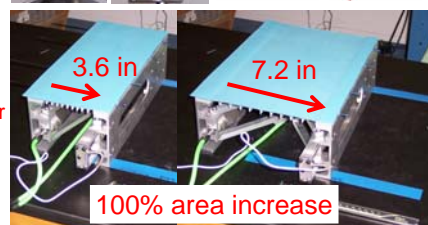
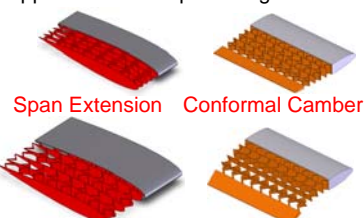
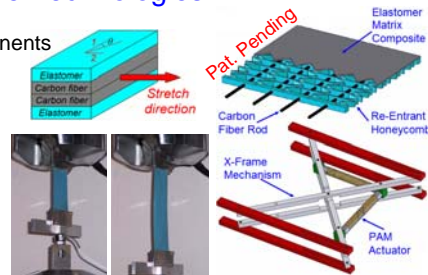


Morphing Structures

Skin and Core Technologies

Morphing system has two key components

- Reinforced skin
 - Actuation mechanism
- Reinforced skin (passive materials)
- Elastomer matrix composite (EMC)
 - Zero-Poisson's ratio core
- Actuation mechanism
- PAM actuators
 - Tailored mechanical advantage
- Applicable to multiple configurations



Comprehensive Design

Hybrid Unsteady Simulation for Helicopters (HUSH)

UMARC can be run with its own aerodynamics

- Useful for preliminary design; validate with CFD
- Suite of CFD tools for CFD/CSD coupling from HQP
- Validated for UH-60, HART II, MDART/SMART
- Morphing capabilities added to OVERTURNS
- TE flap, LE slat, dynamic camber
- Tight-coupling for maneuvers (NASA NRA)

