Compressible Dynamic Stall Control on Helicopter Rotor Blades Using Microjets

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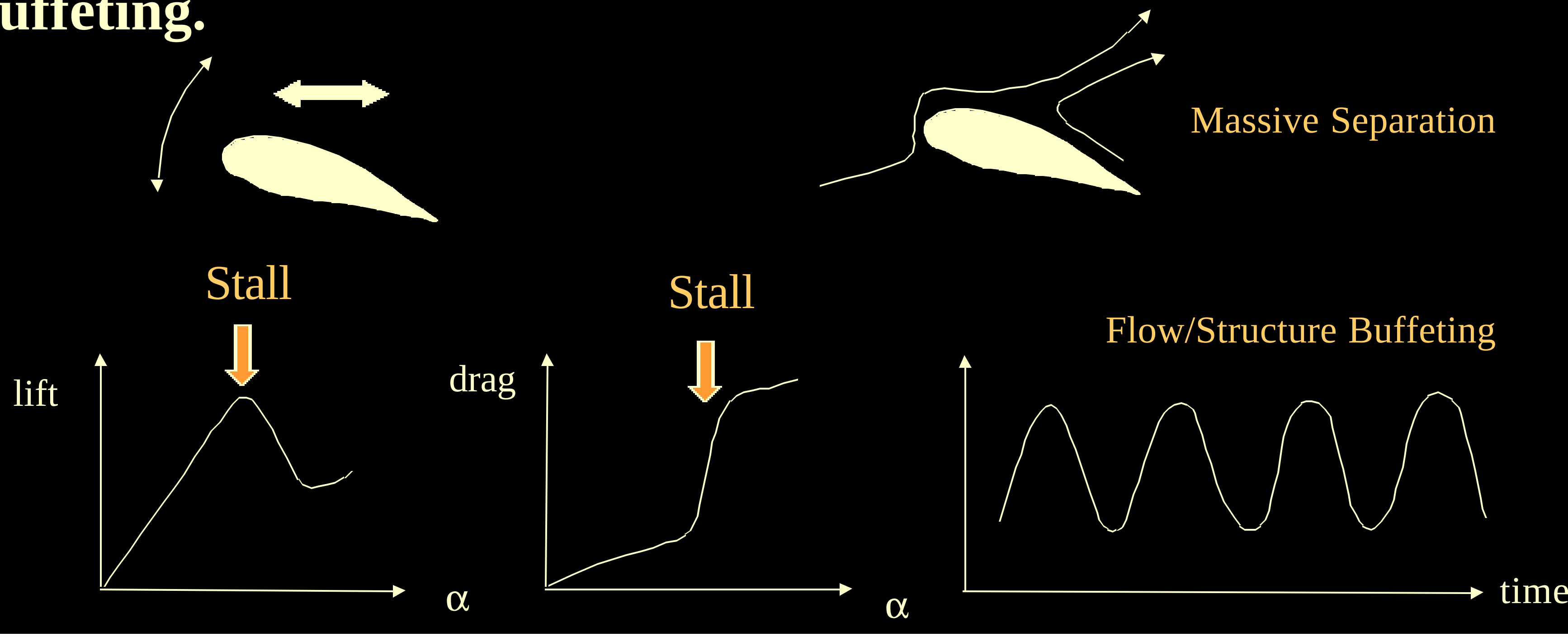
Dynamic stall: a flow phenomenon when wings and rotors experience sudden changes of their operating conditions (angle of attack, inflow conditions, etc). The flow response to these changes usually involves many adverse effects such as massive boundary flow separation, a loss of lift, drag surge, and buffeting.



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Program Objectives

- Eliminate or minimize these adverse effects using microjet control
- Devise control strategy to achieve the optimum effectiveness

Previous control efforts

- boundary layer blowing & suction
- nose modification
- mechanical devices: vortex generators, flaps & slats

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Advantages of using the microjet control as compared to other existing control techniques

- Non-intrusive: no external mechanical device is required; provide no disturbance to the flow.

- Adaptive: can be turned on and off as needed.

- Easy to implement: mass bleeding flow is generally available in helicopters and airplanes.

- In-expensive: no complicated hydraulic/mechanical mechanisms are necessary.

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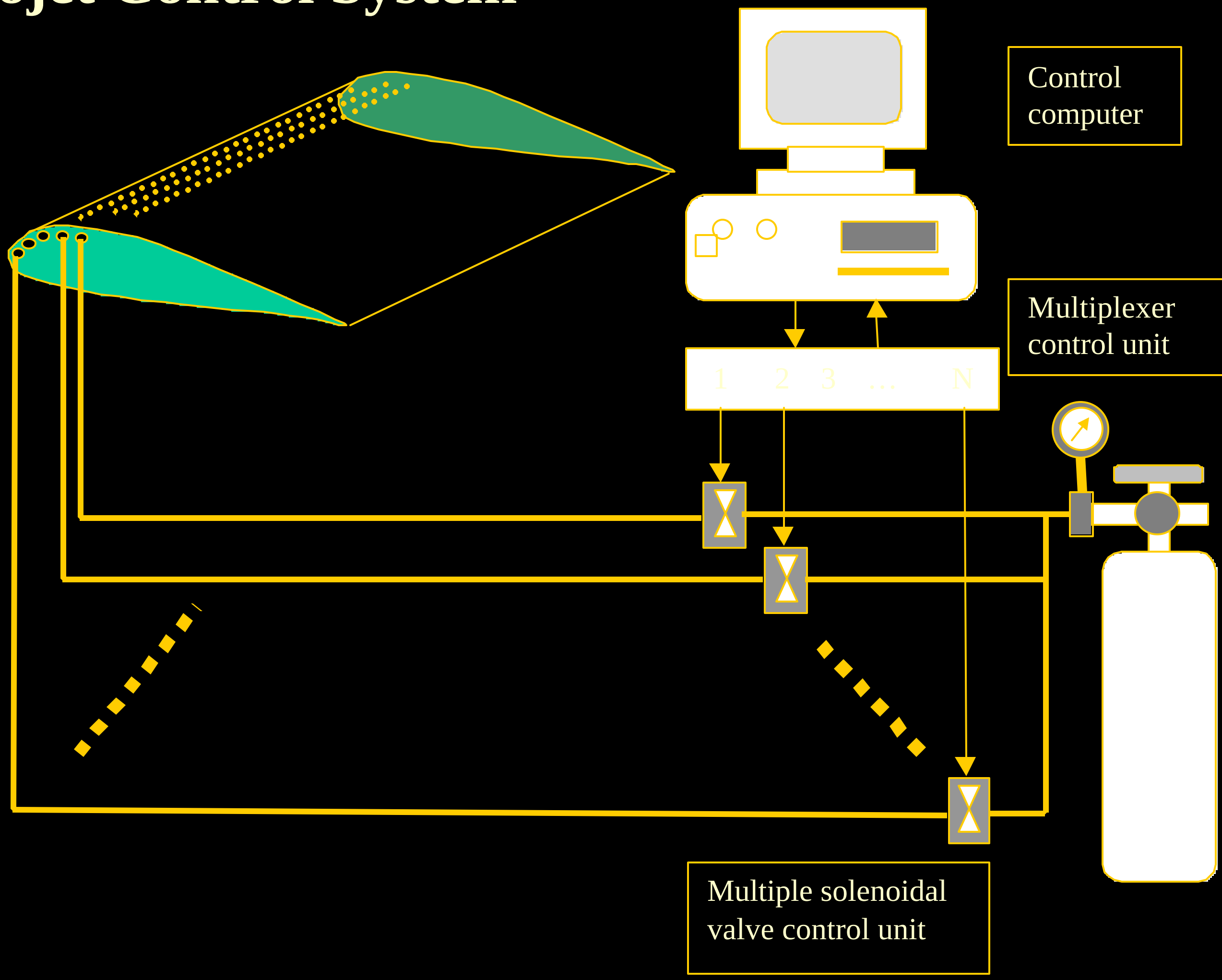
Microjet Control System



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Test Condition

- NACA 0015 Airfoil, 6-inch Chord, Re = 1.1×10^6 at M = 0.3
- Pitch rate k=0.05, pitch angle: 5 to 25 deg.
- Microjet Location: x/c = 0.0 – x/c = 0.12;
  - 500 jets in 8 rows @ $\Delta x/c = 0.015$
- Microjet Dia: 400μm
- Mass Flow Rate: 0.03kg/s @ 22 psia Plenum pressure
- Visualized using Point Diffraction Interferometry (PDI) technique

Massive separation **Flow attachment**

$M = 0.3$, $k = 0.05$, $\alpha = 15 + 10 \sin \omega t = 22.5$deg

No Control Microjet $P_o = 22$psi

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Multiple shocks triggering separation

No apparent shock

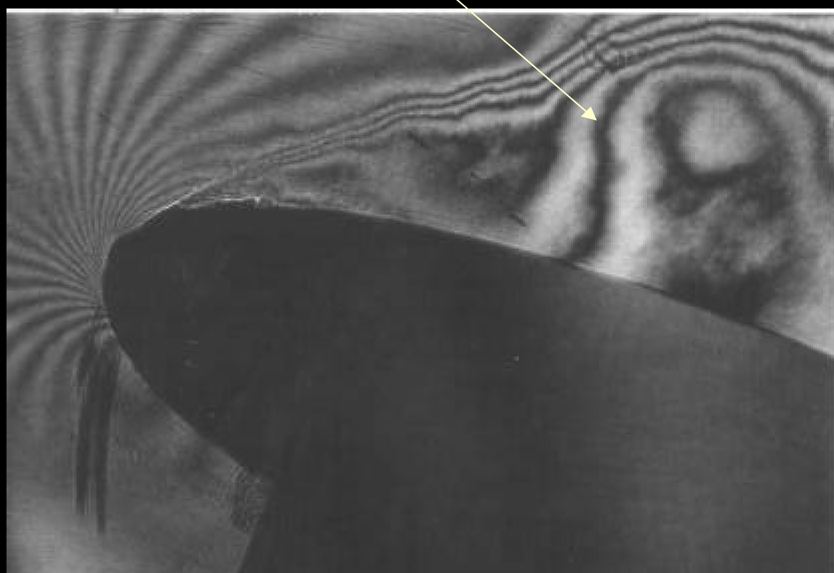
No Control

Microjet P_o = 30 psi

M = 0.4, k = 0.05, α = 10 + 10 sin ωt = 13 deg

Release of dynamic stall vortex

No massive separation
No vortex



No Control

Microjet P_o = 30psi

M = 0.4, k = 0.05, α = 10 + 10 sin ωt = 20 deg

➢ Preliminary Outcomes ⇒ Expected Benefits:

- Dynamic stall has been significantly reduced or eliminated ⇒ improve aerodynamic performance and operational safety.

- Elimination of the shock structures at the leading edge ⇒ alleviating the possibility of the shock-induced separation.

- Suppression of the periodic shedding of the dynamic stall vortex from the wing ⇒ reduce wing fatigue due to buffeting thus extend the life span of a helicopter blade; reduce fluttering noise to increase stealth capability.

Future Work

- Reduce control mass flow rate

- Optimize flow control parameters: pressure, distribution pattern, jet angle, pulsating blowing

- Obtain pressure distribution, lift, and drag measurements to quantify the effectiveness of control

- Apply control to scaled-down helicopter rotor blades

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Other Recent Research Activities

- Micro Flow Characterization (Micro PIV)
- Delta Wing Vortex Control Using Distributed Actuators
- Micro Fluidic Mixer Using Chaotic Mixing
- Dynamics of single DNA molecules in Multiple Stream Flow
- Material Characterization using Laser Speckle Technique
- In-Situ Monitoring of Resin Transfer Molding Process
- Wed-based, Real-Time Laboratory Development