REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
11/07/96

3. REPORT TYPE AND DATES COVERED
Final Technical Report; 11/01/94-6/30/96

4. TITLE AND SUBTITLE
DYNAMICAL EFFECTS OF DELTA WING ACTUATORS ON STREAMWISE VORTICES IN BOUNDARY LAYERS

5. FUNDING NUMBERS
N00014-95-1-0030

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER

19961113 003

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Small delta wing actuators have been constructed and employed in a turbulent boundary layer to provide a disturbance in the wall region. The actuators oscillate perpendicular to the wall with small amplitudes of a few viscous scales. The oscillations set up a spanwise flow of low speed fluid near the wall that coagulates into low speed regions. Since other investigators have found that a spanwise flow near the wall can reduce the drag on the bounding surface, these actuators may be a convenient method to introduce such a spanwise velocity in the near wall region.

14. SUBJECT TERMS
boundary layer, turbulence, control, actuators

15. NUMBER OF PAGES
2

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

Final Technical Report
(N00014-95-1-0030)

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Description of the Scientific Research Goals

The goal of this project was to experimentally ascertain if a delta wing-shaped actuator with small amplitude oscillations could produce a disturbance near the wall that would affect the fluid flow there. The inherent objective was to find a mechanism that would not add significant momentum loss to the flow but still create a perturbation that would alter the near wall turbulent structure.

Significant Results Obtained

The experiments were conducted in the wind tunnel described by Swearingen & Blackwelder (JFM,182,255,1987) at the University of Southern California. The free stream velocity was maintained at 5.0m/sec during these tests. The boundary layer was tripped approximately 0.3m downstream of the leading edge of the test section by a row of small spheres. The actuator consisted of a stainless steel delta wing 2cm wide at the base with a 2.4cm chord mounted flush with the test wall. The stainless steel material continued beyond the 2cm wide base for an additional 2cm. This 2cmx2cm square section had a piezo-ceramic bimorph attached. This was connected to a variable frequency and amplitude power supply which expanded and contracted the two sides of the bimorph. This strain on the sides of the stainless steel provided the movement of the extended triangular actuator section. The power consumed was minimal since the bimorph is primarily a capacitor and had little dissipation. The thickness of the stainless steel was approximately 0.075mm and the bimoph section was 0.30mm thick. For comparison, the thickness of the sublayer (i.e., 5 viscous scales) was 0.30mm also. The delta wing could be oscillated between 1 to 300 Hz with amplitudes of the tip ranging up to 0.6mm.

The results were extremely interesting. When the delta wing was pointed upstream, the actuator did not seem to have any significant effect. However, when it was pointed downstream, the actuator produced two trailing low speed regions; each one lying about 1 to 1.5 cm off the centerline of the actuator. The magnitude of the low speed regions increased as the amplitude of oscillation increased. Their magnitude also increased as the frequency increased up to approximately 200 Hz.

To clarify these results, tests were conducted in a water channel to visualize the flow. The actuator appeared to be creating an "acoustical streaming" type of flow. As the oscillator lifted away from the surface, fluid appeared to move around the edges of the actuator uniformly along its edges and fill the void under the actuator. As the actuator moved toward the wall, the fluid under it was removed non-uniformly; i.e. it was squirted out in primarily the spanwise direction. The actual direction of the outward flow was a function of the free stream velocity and the frequency of oscillation. This low speed fluid collected at a location near to or beyond the location of the wingtip of the actuator and was eventually swept downstream. Hence the two low speed regions were formed by oscillations of the actuator. In all cases the maximum amplitude of the oscillator was less than five viscous units.

Although these results are only preliminary, they do suggest that small delta wing actuators can affect the near wall region of the flow. The most interesting aspect of their effect is that they produce low speed regions with very small amplitude oscillations suggesting that they may provide a means by which the near wall turbulent eddies may be altered with very little expended energy.

Invited Presentations

"Some Recent Results in the Use of Delta-Wing Actuators in the Control of the Streamwise Vortices" at the Workshop on Flow Control, Cargese Corsica, July 1-5, 1996.

"The Use of Actuators to Control the Near-Wall Structure in Bounded Shear Flows," Short Course on Flow Control, Notre Dame University, Sept 9-13, 1996.