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CORRELATION BETWEEN THE OUTER FLOW AND THE TURBULENT PRODUCTION IN A BOUNDARY LAYER

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16. ABSTRACT
Space-time velocity correlation measurements between fluctuations occurring in the convoluting outer edge of a flat plate boundary layer with fluctuations occurring near the viscous subregion have been performed. The correlations indicate that information is propagated from the outer region to the inner region. The migration of turbulence away from the wall has been previously studied in the open literature. The results presented in this report along with the migration results lend support to the "limit cycle" model for turbulence production.

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I. INTRODUCTION

Space-time correlation measurements show a relation between the undulating outer edge boundary layer flow and the turbulent production region near the surface. The observation indicates that information is propagated from the outer region to the inner region.

II. BACKGROUND

The processes involved in the initiation and proliferation of turbulence in the flat plate boundary layer are at present not well understood. Laufer and Bandri Narayanan have presented evidence that the turbulent production mechanism near the wall of a turbulent boundary layer scales with the outer flow parameters [1]. They suggest a "limit cycle" model for the turbulent production which appears consistent with the physical model proposed by Cliff and Sandborn [2].

Kline et al. examined the trajectories of turbulent pockets as they migrated from the near wall region toward the outer regions of the boundary layer [3]. A detailed mapping of space-time autocorrelations of the velocity components was taken across a flat plate boundary layer by Blackwelder and Kovasznay [4]. The mapping gave isocorrelation lines of 0.8, 0.6, 0.4, 0.3, 0.2, and 0.1 for the u component of velocity. Blackwelder and Kovasznay noted that the locus of the maximum space-time correlations was approximately along the trajectory of eddy migration as reported by Kline [3]. The work of Kline et al. [3] and Blackwelder and Kovasznay indicates an outward migration of eddies which are produced in a formation zone near the wall. This migration phenomenon supports the hypothesis that the eddies formed near the wall are ultimately associated with the convoluting outer edge of the boundary layer. A closing of the "limit cycle," proposed and studied in this report, relates the convoluting outer edge to the generation of turbulence near the wall. The convoluting outer edge of the turbulent boundary layer has been shown to produce large perturbations in the local velocities and pressures, as reported by Kovasznay, Kibens, and Blackwelder [5]. It is postulated that the perturbations travel through the boundary layer and give rise to the turbulent production process which occurs near the viscous sublayer. A part of the turbulence produced near the wall, in turn, moves outward and eventually produces the convoluting outer edge of the boundary layer to reproduce and sustain itself. (The motion outward has been shown earlier by Kline et al. [3] and Blackwelder and Kovasznay [4].)

Space-time correlation techniques are a method of examining, at least in part, the inward relation between the undulating outer edge and the turbulent production region of a boundary layer. The space-time correlation of velocity fluctuations occurring in the undulating outer region with velocity fluctuations occurring near the viscous subregion has been performed. The objective of this report is to present the correlation data and interpret the results.

III. TEST SETUP AND PROCEDURE

The experiment was performed in a small, open-return-type wind tunnel. A honeycomb, which is located in a large circular inlet, is used to straighten the inlet flow and break up any large-scale disturbances. From the inlet the flow passes through a settling chamber and then accelerates into a test section, where the cross section narrows to 0.457 m by 0.457 m. The ceiling of the tunnel was adjusted so as to develop a near zero pressure gradient flat plate boundary layer. The correlation measurements were performed at 1.22 m from the start of the test section. Two standard constant temperature hot wire anemometers were used with 0.01 mm diameter platinum iridium wire. Normal annealing and calibration of the hot wires were performed as described in Reference 2.

One hot wire was placed in the undulating outer edge of the boundary layer and one was placed very near the wall. The boundary layer was approximately 7 cm high.

Signals from the hot wires were fed directly into a commercial time delay correlator, RMS meters, and tape transport.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

As was pointed out earlier, Kline et al. [3] and Blackwelder and Kovasznay [4] have performed experiments which support the hypothesis that turbulence generated near the wall migrates outward and is utlimately associated with the convoluting outer edge of the boundary layer.

The following experiment was conceived and performed in an attempt to determine if any correlation exists between the convoluting outer edge and the production region near the wall. That is, to see if there is some correlation which would support a hypothesis of an inward flow of information from the outer edge which may be responsible for the initiation of turbulence near the wall.

Measurements of the correlation between two hot wire anemometer signals (u components), one from the intermittent outer region ($y/\delta = 0.8$) and the other from the turbulent production region of a turbulent boundary layer, have been performed [2].[1] Figure 1 shows a typical space-time correlation curve for the two anemometer signals. The velocity distribution and vertical location of the hot wires are noted in Figure 1. It was found that a measurable correlation existed only for the case where the hot wire in the outer flow was slightly upstream of the probe near the

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[1]The wire in the outer region was well beyond the region investigated by Blackwelder and Kovasznay.

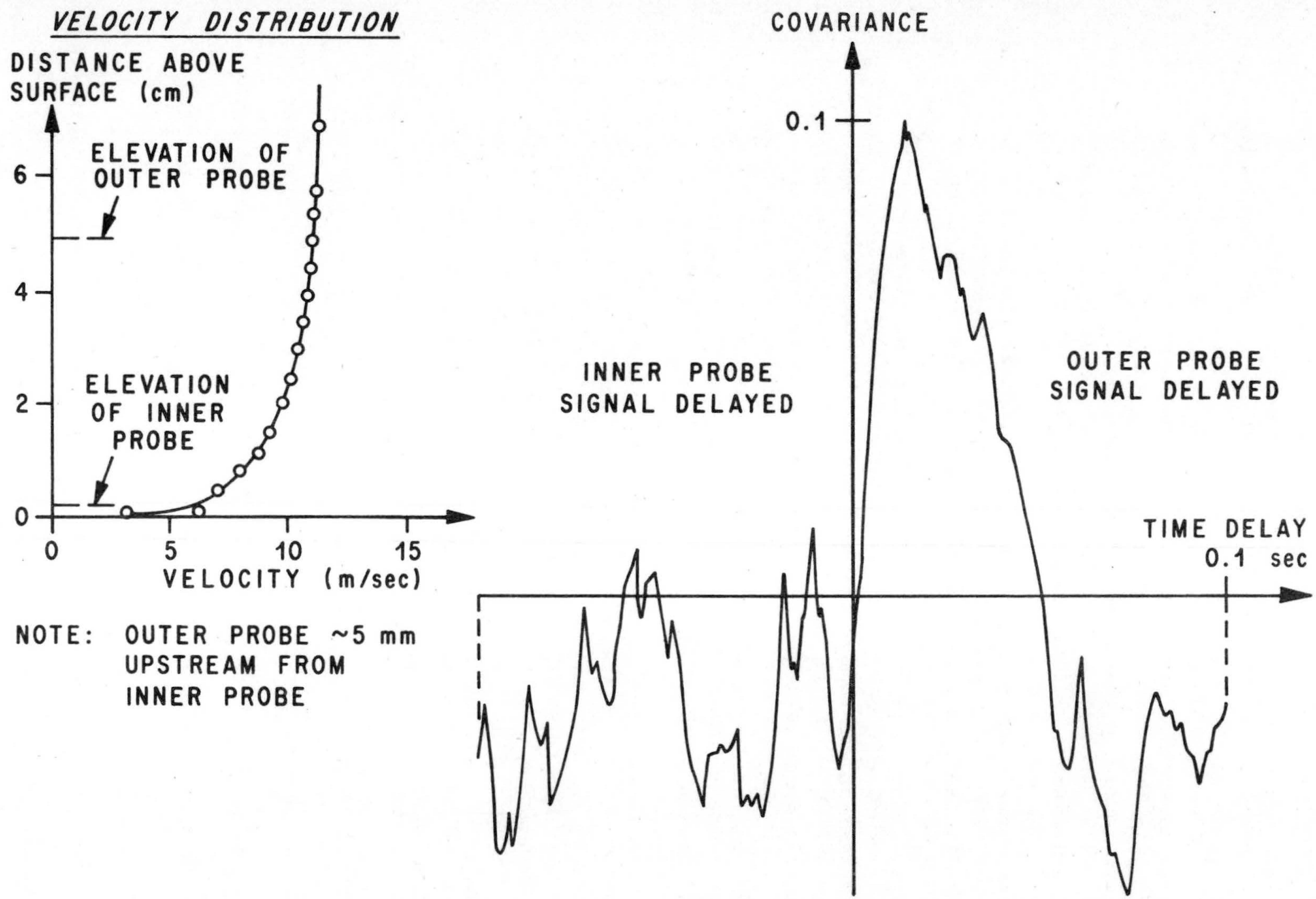

FIG. 1. NORMALIZED CROSS COVARIANCE VS TIME DELAY FOR VERTICALLY SEPERATED HOT WIRE PROBES IN A FLAT PLATE (SLIGHT ADVERSE PRESSURE GRADIENT) BOUNDARY LAYER.

viscous sublayer. No correlation could be measured when the outer ~~other~~ wire was slightly downstream of the sublayer wire. If the wires were in the region investigated by Blackwelder and Kovasznay, movement of the upper wire in the downstream direction would have increased the correlation value [4].

The existence of a correlation between the outer and inner turbulent signals would appear to further support the model suggested by Laufer and Badri Narayanan [1]. The correlation was always found to peak at a time delay other than zero such that information was always sensed first by the outer ~~other~~ probe and later by the inner probe. This shift in time delay indicates that information is propagated inward from the outer region to the wall region of the turbulent boundary layer. No attempt was made to investigate whether or not the "limit cycle" could be closed by the existence of a correlation when the outer wire is far downstream of the wire near the surface, although the work by Kline et al. [3] and Blackwelder and Kovasznay lends support to such a hypothesis.

REFERENCES

1. Laufer, J.; and Badri Narayanan, M. A.: Physics of Fluids, 14, 1971.

2. Cliff, W. C.; and Sandborn, V. A.: Measurements and a model for convective velocities in the turbulent boundary layer, NASA TND-7416, October 1973.

3. Kline, S. J.; Reynolds, W. C.; Schraub, F. A.; and Fundstadler, P. W.: The structure of turbulent boundary layers, JFM, Vol. 30, Part 4, 1967.

4. Blackwelder, R. F.; and Kovasznay, L. S. G.: Time scales and correlations in a turbulent boundary layer, Physics of Fluids, No. 9, 15, 1972.

5. Kovasznay, L. S. G.; Kibens, V.; and Blackwelder, R. F.: Large scale motion in the intermitten region of a turbulent boundary layer. JFM, Vol. 41, part 2, 1970.

APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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