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AN EXPERIMENTAL INVESTIGATION ON LOCATION OF BOUNDARY LAYER TRANSITION ON THE NACA 0012 USING SURFACE HOT FILM GAGES

by

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ABSTRACT

Location of the boundary layer transitions was investigated by attaching the M-1 type surface hot film gages, which were developed on our own, flush to the upper surface of a NACA 0012 airfoil. As shown in a diagram, the location of the boundary layer transitions changed as the angle of attack of the airfoil was varied. Experimental results show that the location of boundary layer transitions using hot film gages is a feasible and practical technique. /401*

1. INTRODUCTION

It is extremely important to determine the location of the interim (transition) region from laminar to turbulent boundary layers on a solid wall. Determination method using surface hot film gages is one of the techniques developed for this purpose. The advantages of this technique are small disturbance on flow (as compared with projection method), convenience for measurements and being insensitive to noise and pressure gradients.

Investigation on the location of the boundary layer transitions

*Numbers in margin indicate foreign pagination using surface hot film gages has been reported in literature [1] and [2]. The characteristics of the experiment described in this paper are attachment of several surface hot films flush to the upper surface of the airfoil to locate the boundary layer transitions and simultaneous use of three different display units to show the signals involved in these films. The objective of this design is to locate the boundary layer transitions at different angles of attack through comparison and verification.

2. PRINCIPLES

Both the projection and laser methods for locating the boundary layer transitions are based on the big differences in the speed types and the turbulence level between the laminar and turbulent boundary layers. In contrast, with the hot film method, the location of these transitions is measured based on the different characteristics of the changes in the wall shear stress at the laminar and turbulent boundary layers, that is, at the same Reynolds number, the wall shear stress at the laminar flow region (equivalent to the time average at turbulent flow) is much smaller than at the turbulent flow, the root mean square of the shear stress is smaller in the former region than in the latter, and the pulse wave patterns in these two different regions are also quite different. After the hot film gages on the model surface are connected to a CTA circuit (constant temperature hot-film and hot-wire anemometer), the three quantities (relative values) mentioned above can be measured by using different display units to determine the location of the transitions. Details about these measurements can be found in reference [3].

In experiments determining the location of the boundary layer transitions, only the relative changes in the wall shear stress need to be measured. Hence, the technique described in [1] and [2] can be used where the voltage output (time average), E is directly used to express the wall shear stress (time average), the root mean square of the pulse voltage, E_{rms} for that of the /402
pulse wall shear stress, and the voltage oscillogram for the pulse wave pattern of the wall shear stress. Here, Both E and E_{rms} have been corrected by subtracting their individual initial readings.

3. EXPERIMENTAL

The experiment was carried out in a 2-D low turbulence level wind tunnel at the Nanjing Aeronautical Institute in 1983. The test section of the tunnel is 6m long, 0.3m wide and 1.2m high with the highest wind speed of 42 m/s and the turbulence level less than 0.08%. The chord length of the NACA 0012 airfoil model, b is 0.15m and its extended length, 0.3m. The model spanned two side walls in the test section of the tunnel. Assuming x being the distance from the front edge along the chord length, each M-1 type hot film was attached flush on the upper surface of the airfoil at x/b=0.4, 0.5, 0.6, 0.7 and 0.8. In the direction of flow, the hot film (thermal film) is 0.05mm long by 0.005mm thick, the thickness of the film base being 0.03mm. Grooves were prepared in advance on the model's surface on which the hot films were to be attached. No steps between the film base and the model's surface were observed after the attachment.

A tsi 1050 type hot-wire, hot-film anemometer was used in this test, together with three displays, tsi 1050 numerical voltmeter (measuring the mean, E), tsi 1070 type root mean square voltmeter (measuring E_{rms}) and MS-5511 memory oscilloscope (giving the pulse wave patterns).

4. EXPERIMENTAL RESULTS

The experimental results are shown in Figs. 1 and 2. Fig. 1 shows the E and E_{rms} vs α, angle of attack curves with different x/b. Fig. 2 shows the oscillograms at five typical angles of attack with x/b=0.7. The vertical deflection sensitivity and /403 scanning speed of the oscilloscope were kept constant during the test. Each division along the horizontal line represents 2ms. The similar wave patterns were found with other x/b values. The Reynolds number $Re_b=\rho v_\infty b/\mu=2\times10^5$.

NACA-type 0012 airfoil is a typical airfoil with medium thickness. The largest thickness appears at 30% length of the airfoil. It can be considered that within the range of angle of attack investigated, the film-attached surfaces are in the adverse pressure gradient region. The larger the angle of attack, the larger this gradient. As shown in Fig. 1 at x/b=0.4, as the angle of attack increases, E first decreases, then suddenly increases to a certain value and finally decreases. If s and r are the minimum and maximum points, respectively, point s represents the beginning at which unstable flow becomes obvious, and point r corresponds to the complete transition of the flow into a turbulent one, i.e., the transition point. Change in E_{rms} with angle of attack is also shown in Fig. 1, where each curve has a maximum between s and r, represented by m. The S, R and M curves were drawn using the s, r and m values in Fig. 1 and taking x/b and α as abscissa and ordinate, as shown in

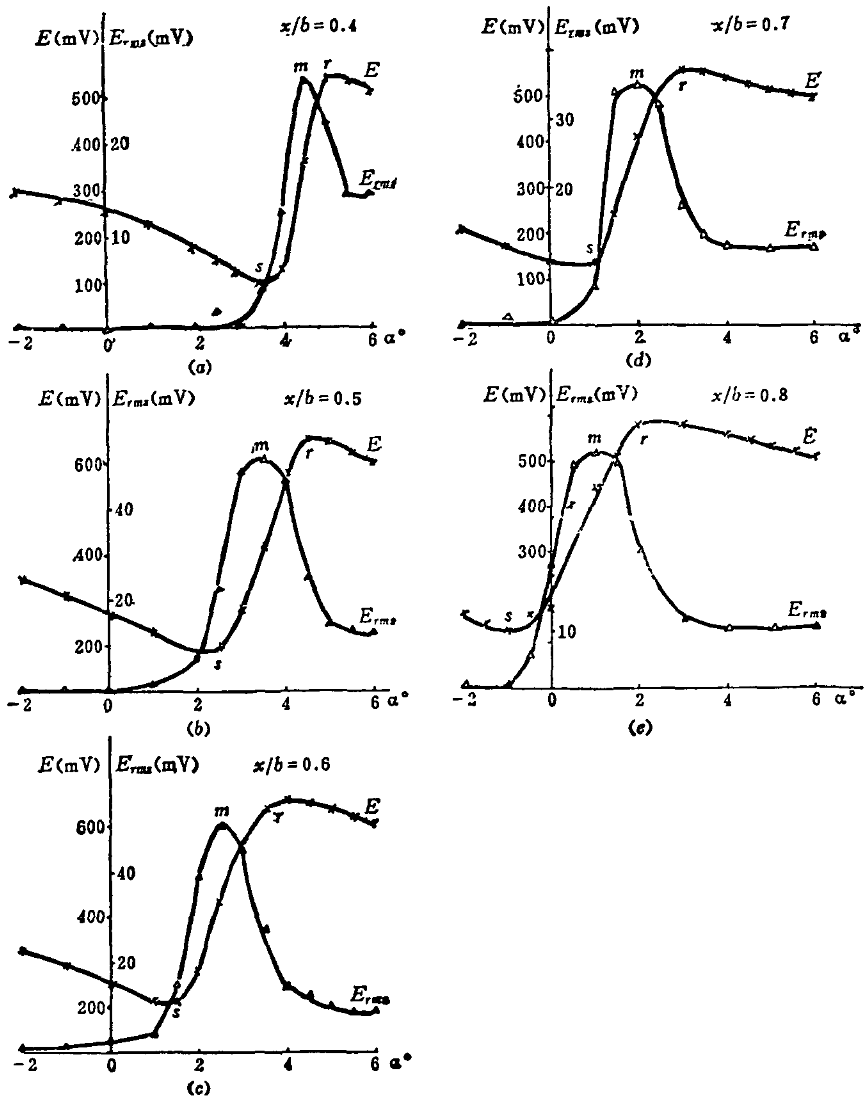

Fig. 1. Variation of E and E_{rms} with angle of attack, at different x/b. X-output voltage, E; Δ-root mean square of the pulse voltage, E_{rms}.

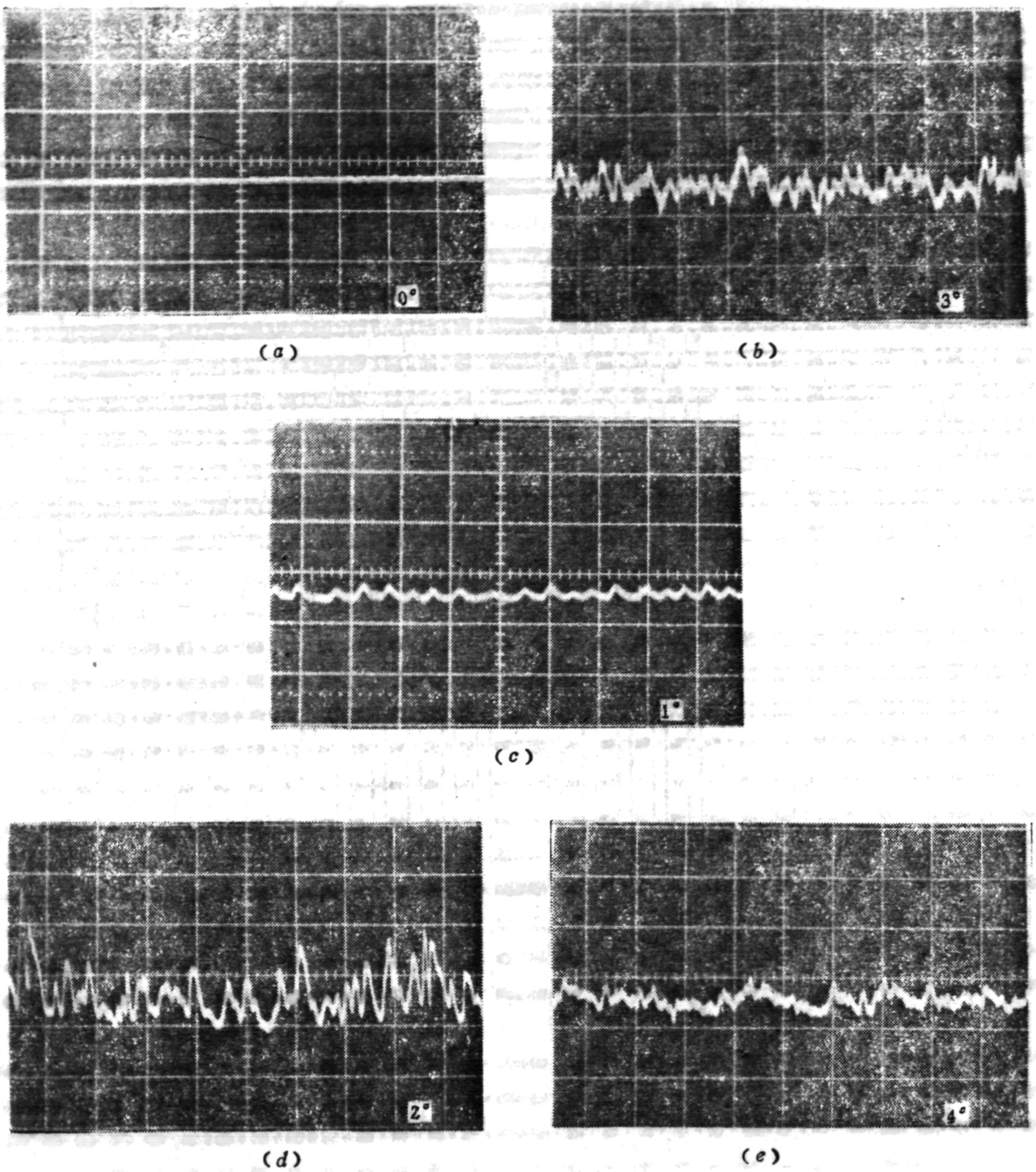

Fig. 2. The oscillograms of the output voltage of the surface hot film gage at x/b=0.7.

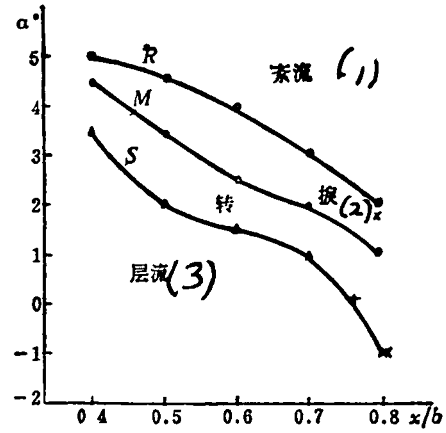

Fig. 3. The location of the boundary layer transitions determined in the experiments.

1-turbulent flow; 2-transition; 3-laminar flow.

Fig. 3. From these three curves, the transition region of the airfoil at different angles of attack can be determined. The results are generally consistent with the rule which states that the transition point moves ahead as the adverse pressure gradient increases. The data points, x and + in Fig. 3 are from the exterior insertion /404 values in the Appendix of reference [1], and reference [4], which are generally consistent with the results obtained in this study.

5. CONCLUSIONS

(1) Surface hot films are promising elements capable of locating the boundary layer transitions.

(2) Location of the boundary layer transitions by using the multilayer surface hot films and measuring the output voltage of the CTA circuit, the pulse voltage root mean square, E_{rms} and the voltage oscillogram is a feasible and practical technique.

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