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**VISUAL STUDY OF FLOW DISCONTINUITY ON 6 x 13" .15 CYLINDRICAL CAMBER AIRFOIL**

(REPORT OF 14" WIND TUNNEL TEST No. 610)

(AIRPLANE SECTION REPORT)

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October 28, 1925

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VISUAL STUDY OF FLOW DISCONTINUITY ON 6x13", .15 CYLINDRICAL CAMBER AIRFOIL

(REPORT OF 14-INCH WIND TUNNEL TEST NO. 610)

PURPOSE OF TEST

The test was made as a supplementary study in connection with wall interference tests (5-foot Wind Tunnel Test No. 134). The angle at which the flow on various thick cylindrical camber airfoils breaks had been seen to change somewhat with speed, size, and turbulence changes; and it was thought to be an aid to the study of these changes to know the character of flow on each side of the critical angle.

It should be noted that the critical angle of these particular airfoils differs considerably from the "burbler point" of the conventional airfoils; this critical angle separates a low efficiency flow regime from a high efficiency regime, but the latter is at higher angles than the critical angle. In conventional airfoils the high efficiency regime is at lower angles than the burble angle (this inversion is a property of thick airfoils of maximum camber unusually far back from the leading edge).

METHOD OF TEST

The flow line method described in report for 14-inch Wind Tunnel Test No. 606 was brought into working use March, 1925, and showed better prospects than other methods previously used. A paint made of kerosene and lampblack in proper proportions is applied to the model under test; the air is turned on, and the kerosene flows due to air friction, scouring channels in the lampblack. The model is previously given a matt coating of light-colored paint, without gloss.

A steel plate was attached to the mid-point of the airfoil, parallel to the line of flow, with a purpose of showing a cross section of the flow at the mid section of the airfoil. This plate was held horizontal, which is the usual position for surfaces tested in the air flow chamber. In addition the wing surfaces themselves were given a coat of the paint. It turned out after making the tests that the most noticeable changes of flow were evidenced on the convex side of the airfoil rather than on the steel plate, and in spite of the detrimental effect of gravity, the tests clearly showed that it was on the surface of the airfoil rather than on the steel plate that the important changes of the critical angle were to be sought. Photographs were taken showing the steel plate, and upper and lower airfoil surfaces for each half degree from 6° to 13° angle of attack and also for zero degrees and for the approximate zero lift angle. The speed in the air flow chamber was about 35 miles per hour. The tip of the airfoil was about 1½ inches from the glass wall of the chamber, so the flow about the airfoil was no doubt somewhat different from normal condition, especially at the tip. The plate may have affected the flow somewhat.

RESULTS OF TEST

The photographs show that the mid-section flow does not change remarkably at the critical angle. The flow over the convex surface, however, shows a distinct change between 8° and 11°. At 8° the flow seems to follow the contour to a point 0.6 the chord from the leading edge. There is a transverse space to the rear of this point, and about 1½ inches wide, in which the flow has left the contour, and this space is filled with ripple marks running transversely to the general air direction.

The strip exists at (−) 6° and 0°, but at 9°, instead of extending from the tip of the airfoil to the steel plate, extends only part way to the steel plate, At 10° the strip reaches only half way to the steel plate, and it is seen that near the steel plate the air flow is holding to the contour better than before (leaving the contour at 0.8 the chord instead of 0.6). At 11° the strip has completely disappeared and the flow follows the contour much better than at 8°; in fact the 0.6 figure has increased to 0.9 near the tip and 0.7 near the steel plate.

Changes in the flow at the bottom of the airfoil are not easily noticeable.

CONCLUSION

The following general conclusions can be made in a preliminary way, pending photographs which are awaited on other more conventional airfoils to be tested in the smoke chamber:

1. The increase of airfoil efficiency noted on the Kx and Ky charts seems to be associated with an improvement of the flow over the upper contour.
2. This improvement first occurs near the midspan of the wing, and at larger angles extends nearly to the tip.
3. The change of flow seems therefore manifest at first near the midspan; and embraces more and more of the airfoil span as the angle increases.

For conclusions of others on the spread of the "Burbling" phenomenon from center of airfoil outwards, refer to N. A. C. A. Report 150 ("Pressure Distribution over Thick Airfoils," Norton and Bacon), and British A. C. A., R. & M. 355 ("The Distribution of Pressure on Upper and Lower Wings of a Biplane," Irving, Powell, and Jones). In other reports the change of flow involves a decrease in efficiency; in the present case it involves an increase; in both cases it starts at midspan and spreads toward the tip.

See Figure 1 for change of Kx and Ky at critical angle, 6° by 36° 0.15 cylindrical camber airfoil at 20 miles per hour.
FIG. 2.—Side view of McCook Field air chamber, showing the model in place.

FIG. 3.—Air flow over 6\times13\,\textsuperscript{\textprime} .15 cylinder camber airfoil at 35 miles per hour \(+13^\circ\)
Fig. 4.—Air flow over $6 \times 13^\prime\prime$.15 cylindrical camber airfoil at 35 miles per hour $+12^\circ$.

Fig. 5.—Air flow over $6 \times 13^\prime\prime$.15 cylindrical camber airfoil at 35 miles per hour $+12^\circ$. 

Fig. 6.—Air flow over 6×13"-15 cylindrical camber airfoil at 35 miles per hour +12°.

Fig. 7.—Air flow over 6×13"-15 cylindrical camber airfoil at 35 miles per hour +11½°.
Fig. 8.—Air flow over 6 x 13" 15 cylindrical camber airfoil at 35 miles per hour +11°

Fig. 9.—Air flow over 6 x 13" 15 cylindrical camber airfoil at 35 miles per hour +11°
Fig. 10.—Air flow over 6 X 13".15 cylindrical camber airfoil at 35 miles per hour +10°59′

Fig. 11.—Air flow over 6 X 13".15 cylindrical camber airfoil at 35 miles per hour +10°59′
FIG. 12.—Airflow over 6×13".15 cylindrical camber airfoil at 35 miles per hour +10°

FIG. 13.—Air flow over 6×13".15 cylindrical camber airfoil at 35 miles per hour +95°
Fig. 14.—Air flow over 6×13°.15 cylindrical camber airfoil at 35 miles per hour +9°

Fig. 15.—Air flow over 6×13°.15 cylindrical camber airfoil at 35 miles per hour +8½°
FIG. 16.—Air flow over 6 x 13° .15 cylindrical camber airfoil at 35 miles per hour +8°

FIG. 17.—Air flow over 6 x 13° .15 cylindrical camber airfoil at 35 miles per hour +7°
FIG. 18.—Air flow over 6×13".15 cylindrical camber airfoil at 35 miles per hour $+6^\circ$.

FIG. 19.—Air flow over 6×13".15 cylindrical camber airfoil at 35 miles per hour $+6^\circ$. 

... (additional text not clear due to image quality)
FIG. 20.—Air flow over 6\times13\textquoteleft\textquoteleft\textquoteleft 15\textsuperscript{°} camber airfoil at 35 miles per hour 0\textsuperscript{°}

FIG. 21.—Air flow over 6\times13\textquoteleft\textquoteLEFT 15\textsuperscript{°} camber airfoil at 35 miles per hour −6\textsuperscript{°}
FIG. 22.—Air flow under 6×13°.15 cylindrical camber airfoil at 35 miles per hour +13°

FIG. 23.—Air flow under 6×13°.15 cylindrical camber airfoil at 35 miles per hour +12½°
Fig. 24.—Air flow under 6×13°.15 cylindrical camber airfoil at 35 miles per hour 12°.

Fig. 25.—Air flow under 6×13°.15 cylindrical camber airfoil at 25 miles per hour 12°.
Fig. 26.—Air flow under 6×12°.15 cylindrical camber airfoil at 35 miles per hour +11½°

Fig. 27.—Air flow under 6×12°.15 cylindrical camber airfoil at 35 miles per hour +11½°
FIG. 29.—Air flow under 6\times 13\textquotedblright .15 cylindrical camber airfoil at 35 miles per hour +10^\circ
Fig. 30.—Air flow under 6×13".15 cylindrical camber airfoil at 35 miles per hour +10°

Fig. 31.—Air flow under 6×13".15 cylindrical camber airfoil at 35 miles per hour +10°
Fig. 32.—Air flow under 6\times 13'' .15 cylindrical camber airfoil at 35 miles per hour +9.5°

Fig. 33.—Air flow under 6\times 13'' .15 cylindrical camber airfoil at 35 miles per hour +9°
Fig. 34.—Air flow under 6×19" .15 cylindrical camber airfoil at 35 miles per hour +45°

Fig. 35.—Air flow under 6×19" .15 cylindrical camber airfoil at 35 miles per hour +8°
FIG. 36.—Air flow under 6X13” .15 cylindrical camber airfoil at 35 miles per hour +7°

FIG. 37.—Air flow under 6X13” .15 cylindrical camber airfoil at 35 miles per hour 0°
FIG. 38.—Air flow under 6 X 13\textquotedblright; .15 cylindrical camber airfoil at 35 miles per hour +6°

FIG. 39.—Air flow under 6 X 13\textquotedblright; .15 cylindrical camber airfoil at 35 miles per hour +6°
FIG. 40.—Air flow under $6 \times 15''$ cylindrical camber airfoil at 35 miles per hour, $-6^\circ$. 