

## EFFECT OF GAP ON SLOPE OF LIFT CURVE AND SLOPE OF LIFT INCREMENT CURVE DUE TO CONTROL SURFACE DEFLECTION

### 1. NOTATION AND UNITS

|                  |                                                                                                                                           | SI                   | British              |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|
| $A$              | aspect ratio                                                                                                                              |                      |                      |
| $a$              | slope of lift coefficient curve with incidence for plain aerofoil (i.e. with no control surface), corrected for aspect ratio and planform | radian <sup>-1</sup> | radian <sup>-1</sup> |
| $a_g$            | slope of lift coefficient curve with incidence for aerofoil with control gap unsealed                                                     | radian <sup>-1</sup> | radian <sup>-1</sup> |
| $a_2$            | slope of lift coefficient increment curve with control surface deflection, gap sealed                                                     | radian <sup>-1</sup> | radian <sup>-1</sup> |
| $(a_2)_g$        | slope of lift coefficient increment curve with control surface deflection, gap unsealed                                                   | radian <sup>-1</sup> | radian <sup>-1</sup> |
| $c$              | wing chord                                                                                                                                | m                    | ft                   |
| $f$              | factor defined by $(a_2)_g = fa_2(a_g/a)$                                                                                                 |                      |                      |
| <i>Subscript</i> |                                                                                                                                           |                      |                      |
| 0                | implies quantities measured in two-dimensional flow                                                                                       |                      |                      |

### 2. NOTES

The ratio  $a_g/a$  is plotted for various chordwise positions of the gap in Figures 1a and 1b. In Figure 1c the factor  $f$  is plotted against balance for three control surface nose shapes. (Balance is defined as the ratio of control surface area forward of hinge line to control surface area aft of hinge line.)

The gap is defined as the smallest distance between the control surface in the undeflected position and the wing surface in front of it (see sketches on the Figures). If the size of the gap varies substantially with control surface deflection, this Item should be used with caution. Experimental evidence suggests that the major effect in reducing the slope of the lift curve is due to the air flow through the gap, but that there is also an effect due to the discontinuity in the aerofoil surface. Values of  $a_g/a$  are based on wind-tunnel tests and are valid only as long as there is no separation of flow over the aerofoil. The curves in Figure 1a refer to two-dimensional flow conditions. The curves in Figure 1b refer to wings of aspect ratio 3 with full-span controls. No information is as yet available for the variation of  $a_g/a$  with aspect ratio between these limits, but it is suggested that linear interpolation is used with  $1/A$  as the variable.

The effect on  $a_2$  of unsealing the gap depends on the factor  $f$  and on the ratio  $a_g/a$ . The factor  $f$  is applicable only within that range of control surface deflections for which  $a_2$  is constant; this limit varies with the size of the control surface, the balance and other factors. Unsealing the gap appears to have only

a small effect on the range of control surface deflections over which the lift coefficient increments vary linearly with control deflection. For the present Item a range of control deflection angles of  $\pm 10^\circ$  has been used.

The control-chord to wing-chord ratio in the tests from which  $f$  has been obtained varies between 0.25 and 0.40; no systematic change of  $f$  with this ratio has been observed over this range, but it is probable that such an effect exists for very large and very small control-chord to wing-chord ratios.

The factor  $f$  shown applies to gaps greater than  $0.004c$ ; for smaller gaps it is suggested that the magnitude of  $(1 - f)$  be reduced linearly with gap size.

For well designed hinge bracket cut-outs, *i.e.* for cut-outs having clearances of the order of the gap size, it is suggested that the gap be assumed to be carried unchanged across the cut-out. Note that this does not apply to hinge moment calculations.

### 3. DERIVATION

The Derivation lists selected sources that have assisted in the preparation of this Item.

- |    |                             |                                                                                                                                                       |
|----|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | NAYLOR, C.H.<br>LYONS, D.J. | An analysis of the lifting characteristics of aerofoils. RAE Rep. aero. 1840, 1943.                                                                   |
| 2. | SEARS, R.I.                 | Wind-tunnel data on the aerodynamic characteristics of airplane control surfaces. NACA advance combat Rep. 3L08, 1943. (Also as ARC Rep. 7986, 1944.) |
| 3. | BATES, W.R.                 | Collection and analysis of wind-tunnel data on the characteristics of isolated tail surfaces with and without end plates. NACA tech. Note 1291, 1947. |

### 4. EXAMPLE

Find the slope of the lift coefficient increment curve with control deflection for a wing of aspect ratio 5 with a full-span control surface with an unsealed gap of  $0.003c$ . It may be assumed that the value of  $a$  for the plain wing is  $3.93 \text{ radian}^{-1}$ , the value of  $a_2$  is  $2.63 \text{ radian}^{-1}$ , the average ratio of control chord to wing chord is 0.35, the control surface nose shape is rounded, and the balance is 0.25, giving a gap position  $0.56c$  aft of the leading edge of the wing.

From Figures 1a and 1b,  $a_g/a$  is 0.895 at  $1/A = 0$  and  $a_g/a$  is 0.950 at  $1/A = 0.333$ . Therefore, interpolating linearly in  $1/A$  for  $A = 5$  gives

$$\begin{aligned}\frac{a_g}{a} &= 0.895 + (0.950 - 0.895) \frac{0.2}{0.333} \\ &= 0.93.\end{aligned}$$

Therefore  $a_g = 0.93 \times 3.93 = 3.65 \text{ radian}^{-1}$ .