CALIBRATION OF LTPT SEMISPAN BALANCE FOR TWO DIMENSIONAL TESTS

A method of calibrating the LTPT semispan balance for two dimensional tests is discussed herein. In the discussion equations are derived for obtaining the lift, drag, and pitching moment coefficients from the balance dial readings recorded during testing. (The coefficients so obtained must still be corrected for tunnel wall effects to get the true coefficients, but these additional corrections are not developed here.)

In the calibration procedure a saddle (fig. 1) is placed around the model at the midspan position. Lift and drag loads are applied separately to the saddle in order to determine the lift and drag calibrations. The position $x_2$ at which the lift load is applied must be known; the drag load is applied along the $x$-axis (fig. 2). The pitching moment calibration is determined from the application of a pure couple $M$ to the saddle.

The application of a pure lift load on the saddle yields the basic lift calibration (fig. 3) and the calibration of the interaction of the lift on the pitching moment (fig. 4) and of the lift on the drag (fig. 5). Similarly, the application of a drag load and a pure couple (separately) yield basic and interaction calibrations (figs. 6 to 8); however, the application of a drag load is assumed to yield no reading on the lift dial, and the application of a pure moment is assumed to yield no reading on either the lift or drag dials.
Symbols:— The following symbols will be used.

LE  airfoil leading edge
EA  electrical axis of balance
L   lift load obtained during tests
D   drag load obtained during tests
L_c  lift load applied during calibration
D_c  drag load applied during calibration
M   pure moment applied during calibration
M_L  pitching moment about EA during calibration resulting from L_c
M_D  pitching moment about EA during calibration resulting from D_c
M_{EA}  pitching moment about EA during tests
M_{c/4}  pitching moment about c/4 line during tests
l   distance from LE to EA
x_2  distance from LE to L_c
x_3  distance from LE to c/4
Δx  distance from c/4 to EA, positive with EA ait of c/4 (= x_1 - x_3).
y  distance from chord plane to EA, positive with EA above chord plane
C  model chord
K_L  slope of calibration curve in figure 3,
K_D  slope of calibration curve in figure 6,
K_M  slope of calibration curve in figure 3,
K_{LD}  slope of calibration curve in figure 5,
R_L  reading of lift dial, counts
R_D  reading of drag dial, counts
R_M  reading of moment dial, counts
R_{0}  reading of various dials with zero forces and moments
K_{LM}  slope of calibration curve in figure 4,
K_{MD}  slope of calibration curve in figure 9,
Lift.— Since the lift dial reading is assumed to be unaffected by drag and pitching moment

$$L = (R_L - R_0)KL$$

or

$$c_L' = \frac{(R_L - R_0)KL}{qS}$$

Drag.— The drag dial reading is affected by the lift and may also be affected by the pitching moment

$$D = (R_D - R_0)KD - \frac{L}{KL_D} KD - \frac{M}{KM_D}$$

$$c_D' = \frac{(R_D - R_0)KD}{qS} - \frac{KD}{KL_D} c_L' - \frac{KM_D}{KL_D} c_L'$$

Pitching moment.— The pitching moment dial reading is affected by both the lift and the drag. In correcting the pitching moment for these interactions, the concept of an electrical axis (EA) is useful. The EA is assumed to be a straight line passing through the balance and across the tunnel such that the application of a pure force normal to this line will yield no reading on the pitching moment dial. In general, this line is not normal to the tunnel wall; its location with respect to the model at the midspan location is required.

From figure 2, the application during calibration of only a known lift load $L_c$ a known distance $x_2$ from the LE yields a moment $M_L$ about the EA as follows

$$M_L = L_c(x_1 - x_2)$$

Thus

$$\frac{x_1}{c} = \frac{M_L}{cL_c} + \frac{x_2}{c}$$

or

$$\frac{\Delta x}{c} = \frac{x_1 - x_3}{c} = \frac{M_L}{cL_c} + \frac{x_2 - x_3}{c}$$

$$= \frac{KM}{cK_{LM}} + \frac{x_1 - x_3}{c}$$
where \( M_L \) is determined by using first figure 4 and then figure 8 and \( \Delta x \) is the calculated distance from the c/4 to the EA.

Also from figure 2, the application of only a known drag load \( D_c \) along the x-axis yields a moment \( M_D \) about the EA as follows

\[
M_D = -D_c y
\]

Thus

\[
y = -\frac{M_D}{cD_c}
\]

where \( M_D \) is determined by using first figure 7 and then figure 8 and \( y \) is the calculated y-position of the EA.

The pitching moment coefficient about the c/4 line during testing is required and may be obtained as follows. We have as the result of the lift and drag loads during a test (refer again to fig. 2) the following moment about the EA

\[
M_{EA} = L(x_1 - x_2) - D_y
\]

where \( x_2 \) is not known. Solving for \( x_2 \)

\[
\frac{M_{EA} + D_y}{L} = x_1 - x_2
\]

\[
x_2 = x_1 - \frac{M_{EA} + yD}{L}
\]

Since

\[
M_{c/4} = -L(x_2 - x_3)
\]

we have

\[
M_{c/4} = -L\left(x_1 - \frac{M_{EA} + yD}{L} - x_3\right)
\]

\[
= M_{EA} - (x_1 - x_3)L + yD
\]

or

\[
\frac{M_{c/4}}{q^2c} = \frac{M_{EA}}{q^2c} - \frac{\Delta x}{c} \frac{L}{c q_S} + \frac{yD}{cq_S}
\]
Now \[ M_{EA} = (R_M - R_0)K_M \]
and define \[ c_m'' = \frac{M_{EA}}{qSc} = \frac{(R_M - R_0)K_M}{qSc} \]
If we define \[ c_m' = \frac{M_0/4}{qSc} \]
then \[ c_m' = c_m'' - \frac{\Delta x}{c} c_L' + \frac{y}{c} c_d' \]

**Factor sheet.** The values of \( c_L', c_d', \) and \( c_m' \) are equivalent to those listed on the factor sheet, one of which is attached. Note changes made in factor sheet which are necessary so that the equations conform to the present calibration procedure.
NOT VALID FOR TESTS AFTER
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LET \( C = \text{CHORD IN INCHES} \)

\[
C_{LTc} = \left( \frac{24}{C} \right) C_{LT24}
\]

\[
R_{24} = \left( \frac{24}{C} \right) R_0
\]

TDT TEST 976 5-8-46
LIFT TARES, TUNNEL EMPTY
BASED ON 24" CHORD

BEFORE SANDING ORIFICES

\[
C_{LT} = \frac{13.957}{\Delta S P} (b_v - b_i) - (c_v - c_i)
\]

\[
R = 8.093 \times 10^6 \frac{K_e \sqrt{\rho \Delta S P}}{R x 10^{-6}}
\]