



Aircraft performance from flight test

Part 3: in-flight calibration of an angle of attack sensor



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AIRCRAFT PERFORMANCE FROM FLIGHT TEST PART 3: IN-FLIGHT CALIBRATION OF AN ANGLE OF ATTACK SENSOR

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1. NOTATION AND DIMENSIONS

		Dimensions
A	angle between R and Oz in Sketch 5.1	—
a_0, a_1	coefficients of first-order polynomial (see Equation (5.26))	—
b_0, b_1	coefficients of first-order polynomial (see Equation (6.6))	—
a_x, a_y, a_z	accelerometer readings along Ox, Oy, Oz directions	LT^{-2}
c_A, c_B	constants of integration (see Equations (5.21) and (5.25))	—
$f [\]$	function of quantity in $[\]$	—
g	acceleration due to gravity	LT^{-2}
H_e	energy height	L
h	altitude	L
I_A	the integral defined in Equation (5.21)	—
MFR	engine intake Mass Flow Ratio	—
n	normal load factor	—
O	origin of axis system	—
p, q, r	rates of roll, pitch and yaw about Ox, Oy, Oz axes	T^{-1}
R	resultant of accelerations a_x, a_y	LT^{-2}
t	time	T
u, v, w	components of aircraft velocity along Ox, Oy, Oz axes	LT^{-1}
u_K, v_K, w_K	components of velocity of aircraft relative to the Earth	LT^{-1}
u_W, v_W, w_W	components of velocity of air relative to the Earth	LT^{-1}
V	velocity along the air-path (true airspeed of aircraft)	LT^{-1}
V_K	resultant velocity of aircraft relative to the Earth	LT^{-1}
V_W	resultant velocity of air relative to the Earth (wind speed)	LT^{-1}

x, y, z	co-ordinates in Ox, Oy, Oz body axes	L
α	angle of attack	—
β	angle of sideslip	—
γ	angle of climb	—
Δ	increment	—
θ	angle of inclination (pitch)	—
ϕ	angle of bank	—
ψ	angle of azimuth	—

Subscripts

0	at time = 0
a	air-path axes
Adj	adjusted value (to normalised conditions)
$Bend$	relating to structural bending
$Down$	in the direction towards the centre of the Earth
$East$	in an easterly direction
E	Earth axes
CG	at the position of the centre of gravity
H	relating to acceleration in heave (angle of attack changing with time)
i	indicated value
$Meas$	measured
MFR	relating to engine intake mass flow ratio
$North$	in a northerly direction
R	value registered by sensor
S	sensor position

In line with convention, the terms airspeed and wind speed are used in this Data Item even though they are vectors and consequently should be referred to as velocities.

2. INTRODUCTION

Determination of the incidence angles of an aircraft is fundamental to the derivation of a performance model from flight testing. The primary requirement is for knowledge of the effective angle of attack at the aircraft centre of gravity. An indication of the angle of sideslip may also be used to ensure there is no significant motion normal to the plane of symmetry and to account for any motion if appropriate.

Various types of sensor can be used for the purpose of determining these angles.

These flow angle sensors may be located either ahead of the aircraft on a boom or directly on the fuselage. For any position the sensor will measure the local flow angle rather than the true angle of attack or sideslip. The difference between the measured and true angle, sometimes referred to as the position error, is a function of upwash (determined by lift coefficient), sidewash and Mach number. Depending on the location of the sensor, local upwash and sidewash may also be a function of undercarriage position, flap deflection and stores carriage.

The position of the sensor on the aircraft and the manoeuvres flown will determine the extent to which the sensor readings may be affected by angular velocities of the aircraft, structural distortion in the form of boom and/or fuselage bending under load and engine operating condition. These effects will need to be accounted for both in producing a calibration and in subsequent use of the calibration to determine true angles of attack and sideslip.

In order to derive a calibration of the flow angle sensor it is necessary to determine the true angles of attack and/or sideslip through a sequence of manoeuvres on a test aircraft. In this Data Item a number of methods are discussed for determining these angles. The choice of method depends on the level of instrumentation on the test aircraft.

3. TYPES OF SENSOR

Angles of attack and sideslip are determined in flight by measuring the local flow direction at some point on the airframe and then relating that to angle of attack or sideslip at the aircraft's centre of gravity. Flow direction can be measured by one of a number of sensors which include the following.

(a) *Vanes*

Mass balanced vanes are mounted on the aircraft such that they are free to rotate to align with the flow direction, one rotates about the local y -axis to determine angle of attack and one about the local z -axis to determine sideslip. Vanes may be fixed to a boom mounted on the nose (or wing) of the aircraft, possibly making use of a Pitot-static boom if fitted. Alternatively, they may be fixed to the forward fuselage.

(b) *Airstream Direction Detector (ADD)*

The ADD is a null-seeking, differential pressure sensor. The sensor rotates until the pressure in upper and lower chambers are equal, that is when the sensor is aligned with the local flow direction. The ADD is mounted on the aircraft's fuselage side to determine angle of attack, it can also be mounted on the top or bottom of the aircraft nose to determine angle of sideslip.

(c) *Differential pressure probes*

An example of this technique is the five hole probe. Five pressure sensing holes are arranged on a truncated cone or hemisphere. One hole is in the centre (to measure total pressure) and four holes are arranged equi-distant around the face of the cone, or hemisphere. The difference in pressure sensed by opposing holes is a measure of local flow direction. This pressure difference from