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Example of statistical analysis of wet runway friction: aircraft with limited set of test data

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EXAMPLE OF STATISTICAL ANALYSIS OF WET RUNWAY FRICTION:
AIRCRAFT WITH LIMITED SET OF TEST DATA

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EXAMPLE OF STATISTICAL ANALYSIS OF WET RUNWAY FRICTION: AIRCRAFT WITH LIMITED SET OF TEST DATA

1. NOTATION, UNITS AND DEFINITION

The units given in this section are coherent sets – as are required for equations throughout the Data Item. However, where numerical values are quoted, customary British units are used for d_{tex} , p , q and V_{bo} .

1.1 Notation

C_{D_G}	aerodynamic drag coefficient for aircraft in ground-roll attitude (see Section 3 for values)	–	–
C_{L_G}	aerodynamic lift coefficient for aircraft in ground-roll attitude (see Section 3 for values)	–	–
D_G	equivalent mean value of aerodynamic drag for aircraft in braked ground roll (taken as, $\rho(V_{bo}/2^{1/2})^2 S C_{D_G}/2$, see Section 3.1)	N	lbf
d_{tex}	runway surface macro-texture depth	m	ft
$E[]$	expected or calculated value of quantity in square brackets, that is corresponds to $P_E = 0.5$	–	–
G_B	tangential force on tyre due to braking	N	lbf
g	acceleration due to gravity (32.1740 ft/s ²)	m/s ²	ft/s ²
L_G	equivalent mean value of aerodynamic lift for aircraft in braked ground roll (taken as, $\rho(V_{bo}/2^{1/2})^2 S C_{L_G}/2$, see Section 3.1)	–	–
n	size of sample	–	–
P_E	probability of exceedence	–	–
p	tyre inflation pressure	N/m ²	lbf/ft ²
q	kinetic pressure of runway surface water (= $\rho_w V_G^2/2$)	N/m ²	lbf/ft ²
R_{braked}	sum of normal (to runway) reactions at braked (main) wheels	N	lbf
S	wing reference area (= 180 ft ²)	m ²	ft ²
s	aircraft stopping distance from speed V_{bo} to stop	m	ft
s_{dry}	value of s in dry-runway conditions	m	ft
s_{wet}	value of s in wet-runway conditions	m	ft
V_{bo}	ground speed for “brakes-on”	m/s	ft/s
V_G	ground speed	m/s	ft/s
W	aircraft weight	N	lbf
Z	normal (to runway) load on wheel	N	lbf
z	percentage point in Standard Normal Distribution	–	–

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β	parameter defined in Equation (4.1)	—	—
κ	tyre-to-wet-runway interaction parameter, $(\beta d_{tex})^{1/2}$	$m^{1/2}$	$ft^{1/2}$
$\bar{\kappa}$	mean value of κ	$m^{1/2}$	$ft^{1/2}$
μ	coefficient of friction, G_B/Z	—	—
μ_{datum}	datum value of μ at $V_G = 0$ on dry runway	—	—
μ_{eff}	effective tyre-runway coefficient of friction for aircraft (includes effects of anti-skid system)	—	—
ρ	density of air (taken as ISA sea-level value)	kg/m^3	$slug/ft^3$
ρ_W	density of water (taken as 1000 kg/m^3 or 1.94 slug/ft^3)	kg/m^3	$slug/ft^3$
$\sigma[\]$	standard deviation of quantity in square brackets	—	—
Φ	Standardised Normal Cumulative Distribution Function, see Reference 2 for numerical values	—	—

1.2 Definition

For aircraft, μ ($\equiv \mu_{eff}$) is the effective coefficient of friction deduced from braked ground runs and includes the effects of the aircraft anti-skid system. For the present method to be applicable it is *essential* that those runs provide values of μ_{eff} that relate to “friction-limited” braking and not values constrained by the effects of brake torque or energy limits or the intervention of a pre-set level of “auto-braking”.

2. INTRODUCTION

This Data Item is the second of a series of examples of the application of a method for representing – and, if necessary, relating – the braking performances of aircraft and ground-test machines in wet conditions. The method, which is given in Reference 4, is essentially statistical and implies that there is a clearly-defined level of probability that can be deduced from test runs of an aircraft (or ground-test machine) in a given set of wetness conditions on a particular runway. If the runway macro-texture depth is known, then the parameter that defines the variation of effective coefficient of braking friction in the given conditions can be readily calculated from a pre-determined *Friction Data Base*. The concept of a Friction Data Base is explained in Reference 4.

The Item uses test data collected from a short trial on a small combat aircraft to illustrate the way in which a very limited amount of information can be used to establish a Friction Data Base. For this aircraft the data were limited in so far as the tests were made on a single runway and the measured quantities were “brakes-on” speed and stopping distance. The background to those tests is described in Section 3. The methods of analysis are summarised and results are presented in Section 4.

The first example, for an aircraft where an extensive set of test data is available, is given in Reference 5. An example of the application of the method to ground-test machine data is given in Reference 6. Many other examples are considered in Reference 3.

If the method of Reference 4 is to be used to *relate* the braking performances of a given combination of aircraft and ground-test machine, the procedure is comprised of two distinct phases. The first is the establishment of separate *Friction Data Bases* for the aircraft and for the ground-test machine. The second is the prediction of operational braking performance of the aircraft using day-to-day measurements from the ground-test machine.