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Planing of rib-tread aircraft tyres



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PLANING OF RIB-TREAD AIRCRAFT TYRES

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PLANING OF RIB-TREAD AIRCRAFT TYRES

1. NOTATION, DIMENSIONS AND DEFINITIONS

1.1 Notation and Dimensions

		Dimensions
$(C_G)_{DISP}$	coefficient of decelerating force	–
$(C_L)_H$	hydrodynamic lift coefficient	–
c_0, c_1, c_{01} c_{10}, c_{11}, c_{12}	coefficients in decelerating-force model	–
D	inflated diameter of tyre	L
d_C	contaminant depth	L
d_{TEX}	depth of surface macro-texture	L
G_{DISP}	decelerating force due to displacement of fluid by tyre	M L T ⁻²
L_H	hydrodynamic lift	M L T ⁻²
N	speed number (see Equation (4.2d))	–
p	inflation pressure – gauge (in lbf/in ²)	M L ⁻¹ T ⁻²
p_{ABS}	inflation pressure – absolute measure	M L ⁻¹ T ⁻²
q	kinetic pressure	M L ⁻¹ T ⁻²
S_{DISP}	reference area for calculation of hydrodynamic decelerating force	L ²
S_F	reference area for footprint	L ²
V_G	ground speed	L T ⁻¹
V_H	speed at which complete planing occurs	L T ⁻¹
V_P	previously recognised hydroplaning speed (in knot)	L T ⁻¹
V_S	speed at start of planing	L T ⁻¹
w	inflated width of tyre	L
Z	vertical force on wheel	M L T ⁻²
μ_{SKID}	coefficient of friction in full skid	–
ρ_C	density of water	M L ⁻³
$1/\tau$	drainage parameter	–

Subscripts

H hydroplaning

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1.2 Definitions

<i>Coefficients of force</i>	are defined as the ratio of (horizontal) force and the normal (to the runway) force so that consistency with customary practice is maintained.
<i>Contaminated</i>	is defined as a condition of a runway covered by a medium that practically obscures the natural surface from a travelling pneumatic tyre. The description includes a flooded runway but not a damp nor wet runway.
<i>Drainage parameter</i>	is the ratio of depth of free-standing water on, and the total depth of water on and in, the surface.
<i>Fineness Ratio</i>	is the quotient of tyre (inflated) width and tyre (inflated) diameter.
<i>Footprint</i>	is the term used for the area of contact between tyre and runway surface.
<i>Micro-texture</i>	is the deviation of a pavement from a true planar surface with characteristic dimensions over the surface less than 0.05 mm (0.002 in). On airfields at the time of writing, surfaces are normally constructed to ensure that micro-texture is significantly rough.
<i>Macro-texture</i>	is the deviation of a pavement from a true planar surface with characteristic dimensions over the surface in the range 0.05 mm to 5 mm (0.002 in to 0.2 in). On airfields at the time of writing, it is unusual for macro-texture depth to lie outside the range 0.5 mm to 2 mm (0.02 in to 0.08 in).
<i>Speed number</i>	is a dimensionless number relating kinetic pressure in a fluid and inflation pressure of a tyre moving through the fluid (see Equation (4.2d)).
<i>Partial planing</i>	is a condition in which a tyre has started to spin down under the influence of lift generated by motion through a fluid medium and is supported partially by that lift.
<i>Complete planing</i>	is the condition in which a tyre has spun down completely under the influence of lift generated by motion through a fluid medium and is supported solely by that lift.

2. INTRODUCTION

Planing was recognised as a specific aircraft problem in the decade following the Second World War when aircraft ground speeds increased and airfield surfaces were constructed and maintained at macro-texture depth, d_{TEX} , less than 0.01 in. As a consequence, testing from that era was conducted on surfaces that are substantially less well-drained than those on which modern aircraft operate. Furthermore, the facilities provided at such institutions as Cranfield Institute of Technology, were built at a slightly later time when macro-texture depths were only just beginning to increase. Thus the surface used there, near the turn of this century for flooded runway studies, in which $d_{TEX} = 0.02$ in, is quite limited in terms of modern standards of drainage.

All the testing that has been found from which planing conditions can be deduced was conducted so that the **rib-tread tyres** were rolled through water depths well in excess of the tread depths. Thus the drainage parameter is not less than approximately 0.95 for any of the test results available for analysis. In the customary assessment, account is taken only of the inflation pressure of the tyre with no attention paid to the effects of runway condition or tyre geometry. Reference 1 does consider tyre geometry but pays no attention to the likely effects of surface condition.

For modern runways, with depths of the macro-texture that can approach $d_{TEX} = 0.08$ in, it is probable that the drainage parameter is close to 0.8. Because there is a substantial effect due to surface drainage on planing phenomena it is necessary to modify the customary approach. This can be achieved most reasonably by considering the algebraic relations that describe the effects of runway condition and tyre fineness-ratio on the decelerating forces that develop on pneumatic tyres in motion over runways covered in water.

Thus the modelling procedure of References 2 and 3 is used in Section 4 to deduce a variety of speeds that fulfil many of the customary definitions of planing. Data from all the relevant experiments are described in Section 5.

Insights into the problem of planing from the various historical references are summarised and discussed in Sections 5 and 6. Conclusions and recommendations are set out in Section 7.

3. PLANING CONDITIONS

It is conventional to describe as **planing** at least six conditions that arise when pneumatic tyres are rolled and/or braked on plane, wet surfaces. These are

1. significant reduction of the water spray from tyre,
2. tyre spin-down,
3. fluid drag reaches peak value,
4. loss of contact between tyre footprint and ground surface,
5. loss of tyre directional stability,
6. loss of (significant) braking action.

Because these conditions do not necessarily occur at the same speed during any motion, there is no unique speed that can be precisely described as “*the planing speed*”.

The first three of these conditions are most likely to be associated with a freely rolling tyre but can also apply to a slipping tyre. These conditions are generally defined as **partial** planing. The first is purely subjective, there is no accepted definition as to what amount of reduction in spray is significant. In an accelerated motion, the second occurs at a speed somewhat lower than the third, whilst in a decelerated motion, the wheel does not spin up until the speed is lower than that for maximum drag. In particular, the wheel may spin up at a speed less than the spin-down speed. It is of note that a tyre that has spun down completely, appears to produce the same braking action as that for a skidding tyre.

The second group of three conditions can be assumed to occur simultaneously. In practice, the only condition that can be uniquely determined by observation is the loss of **all** braking action and side force, that is, when the coefficient of **braking** friction reduces to zero. In References 3 and 4 it is shown that this occurs under conditions that are determined by speed, inflation pressure (in absolute measure), depth of water above the surface, and the depth of the surface macro-texture. Similarly, it is shown in Reference 5 that side-forces reduce to zero under the same conditions of speed, inflation pressure, and drainage parameter. These conditions are defined as **complete** planing.