



**Tyre in linear motion on a runway covered
by various forms of loose snow.
An application of ESDU 05011**



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TYRE IN LINEAR MOTION ON A RUNWAY COVERED BY VARIOUS FORMS OF LOOSE SNOW. AN APPLICATION OF ESDU 05011

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1. INTRODUCTION

This Data Item forms part of a series of worked examples. These examples illustrate the application of the method for estimating the decelerating forces acting against a single aircraft tyre operating on a dry or contaminated runway surface described in Reference 1. Reference 4 is worked example in which the method is applied a single aircraft tyre operating in linear motion on a runway surface that is covered by various forms of contaminant, whilst Reference 5 demonstrates the application of the method to continuous friction measuring equipment (CFME). A complete description of the method is given in Reference 2, whilst background information relating to its application can be found in Reference 3.

A tyre is operating in a braked state on a runway that is covered by a layer of loose snow. A number of different types of loose snow are considered and the properties of each layer analysed are listed in Table 2.2. In each instance, the layer is considered to be uniform across the entire runway surface. The snow water content, ϕ_{WET} , and snow density, ρ_{SNOW} , vary for each case considered.

It is necessary to determine the decelerating forces acting on the tyre when it is operating at a ground speed of 60 knots.

The tyre and runway are identical to those described in Reference 4 and some information used in this Data Item is taken from that document.

Notation from Reference 1 and, where applicable, the values of the constant terms that appear in Table 5.1 of the document are used throughout this Data Item. Familiarity with Reference 1 is recommended before reading this Data Item.

2. ASSUMPTIONS

2.1 Aircraft and Tyre Information

The relevant tyre data are listed in Table 2.1. The tyre is assumed to have a rib-tread.

TABLE 2.1 Aircraft tyre data

Tyre parameter	Value	Unit
D	41 (3.4167)	in (ft)
w	14 (1.1667)	in (ft)
p	160 (23040)	lbf/in ² (lbf/ft ²)
p_{ABS}	174.7 (25156.8)	lbf/in ² (lbf/ft ²)
μ_{REF}	1.02 [†]	—

[†] This value is obtained from Table 5.1 of Reference 1.

From Reference 4, the normal load acting on the tyre, Z , has a value of 22500 lbf when the ground speed, V_G , is 60 knots. The slip ratio, s , at this speed is 0.1.

2.2 Runway Conditions

a) Layers of contaminant covering runway surface

The layers of contaminant to be considered in this example are listed in Table 2.2.

TABLE 2.2 Layers of contaminant considered for analyses

Contaminant type	ρ_{SNOW} (slug/ft ³)	ϕ_{WET}	d_{SNOW}	T (°C)	$\Pr[z]^\dagger$ (%)	z
Moist loose snow	0.194	0.02	10×10^{-3} m (3.2808×10^{-2} ft)	-1	5	-1.6449
Wet loose snow	0.776	0.05	10×10^{-3} m (3.2808×10^{-2} ft)	-1	5	-1.6449
Very wet loose snow	1.164	0.1	10×10^{-3} m (3.2808×10^{-2} ft)	-1	5	-1.6449

[†] $\Pr[z]$ denotes the percentile from the Normal distribution that is assumed when deriving the reference coefficient of friction for the case where a tyre is braked on a runway surface that is covered by a layer of loose snow. In a practical application, a value appropriate for the situation should be selected.

b) Macro-texture depth of runway surface

The macro-texture depth of the runway surface, d_{TEX} , is 0.03 in (2.5×10^{-3} ft). This value is assumed for each instance.

c) Runway surface temperature

In each analysis considered, the runway temperature, T_G , is 0°C.

2.3 Ambient Conditions

For all cases ISA, Sea Level pressure (14.7 psi, 1013.2 mb) is assumed.

3. DETERMINATION OF TOTAL DECELERATING FORCE ACTING ON TYRE WHEN CONTAMINANT IS MOIST SNOW

In this Section, the method defined in Reference 1 is applied for the case where the runway is covered by the layer of moist loose snow that is specified in Table 2.2.

The values of terms that are not listed in this Data Item can be found in Table 5.1 of Reference 1.

3.1 Determination of Rolling Resistance

The method for determining the rolling resistance of a tyre is listed in Table 5.2.1 of Reference 1. A detailed description of the implementation of the method is given in Section A.1 of Reference 4.

Following this procedure, the rolling resistance of the tyre, G_{ROLL} , is 216.0 lbf.

3.2 Determination of Contaminant Drag Force

For moist snow, the contaminant drag force acting against a single tyre that is displacing snow, G_{SNOW} is calculated using the following relationships from Table 5.2.3 of Reference 1.

$$G_{SNOW} = \left(\frac{\sigma_{SNOW}}{p_{ABS}} \right) \left(\frac{Z d_{SNOW}}{2a} \right) \left(\frac{1}{n-1} \right) \left(\left(\frac{p_{ABS}}{\sigma_{SNOW}} \right)^{(1-1/n)} - 1 \right) + (d_{RUT})_{COM} \left(\frac{Z}{p_{ABS}} \right)^{1/2} \frac{\tau_{SNOW}}{\lambda} \tanh \left[\eta \frac{\rho_{SNOW} V^2}{\tau_{SNOW}} \right], \quad (3.1)$$

where $a = D \left\{ \alpha_1 \alpha_2 \tanh \left[2 \frac{\delta}{w} \right] / \tanh \left[0.5 \frac{w}{\delta} \right] \right\}^{1/2},$

$$(d_{RUT})_{COM} = d_{SNOW} \left(1 - \left(\frac{\sigma_{SNOW}}{p_{ABS}} \right)^{1/n} \right),$$

d_{SNOW} is the depth of snow,

$$\frac{\delta}{w} = \alpha_0 \Lambda^{3/4},$$

$$\Lambda = \frac{Z}{\kappa p_{ABS} \pi w D},$$

$$\eta = \frac{\lambda_{273}}{1 + \frac{(1 - T/T_{REF})}{\lambda_{273}}},$$

$$\sigma_{SNOW} = (1 + \Theta)^3 (\sigma_{SNOW})_{REF} \left(\frac{\rho_{SNOW}}{\rho_{ICE}} \right) \left(a_0 \left(\frac{\rho_{SNOW}}{\rho_{ICE}} \right) + \tanh \left[\frac{1}{a_1} \left(\frac{\rho_{SNOW}}{\rho_{ICE}} \right)^5 \right] \right),$$