



Drag of transverse rows of spherically-headed rivets immersed in a turbulent boundary layer at subsonic and supersonic speeds

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DRAG OF TRANSVERSE ROWS OF SPHERICALLY-HEADED RIVETS IMMERSED
IN A TURBULENT BOUNDARY LAYER AT SUBSONIC AND SUPERSONIC SPEEDS

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1. NOTATION AND UNITS

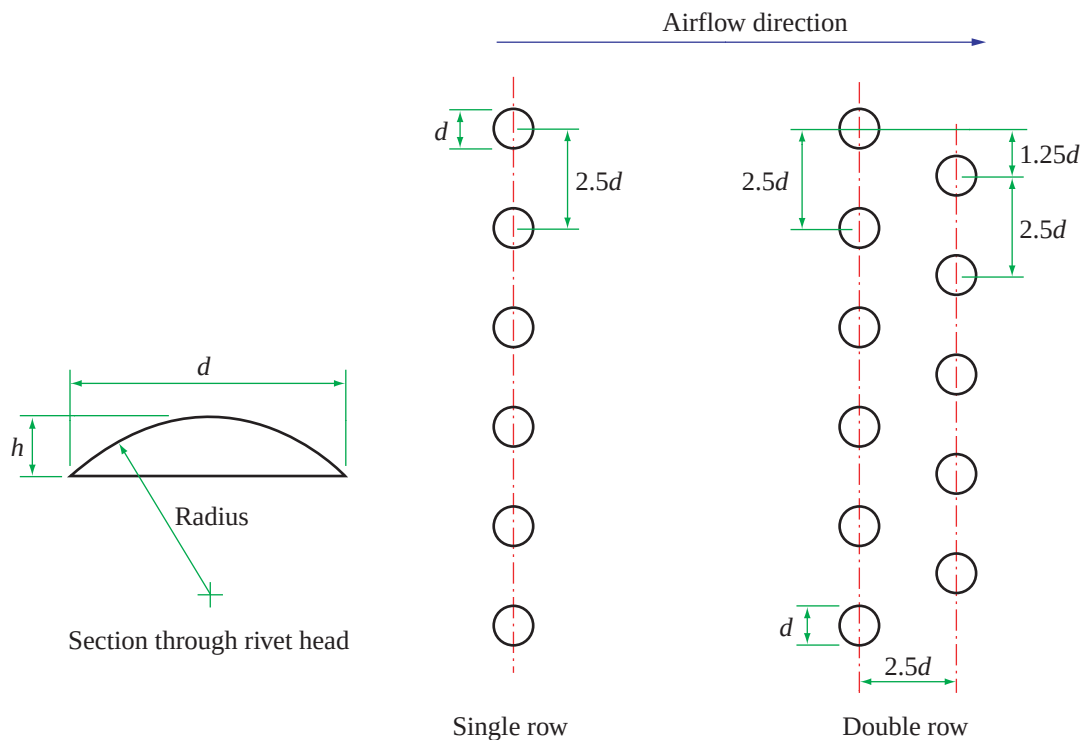
		SI	British
C_D	incremental drag coefficient due to transverse rows of rivets based on frontal area ($S \times$ number of rivets) and kinetic pressure at edge of undisturbed boundary layer		
C_f	local skin friction coefficient in absence of rivets, based on kinetic pressure at edge of boundary layer		
d	planform diameter of rivet head (see Sketch 2.1)	m	ft
h	height of rivet head (see Sketch 2.1)	m	ft
M_1	Mach number at edge of undisturbed boundary layer		
R_h	Reynolds number based on velocity and kinematic viscosity, both at edge of undisturbed boundary layer, and h		
R_x	Reynolds number based on velocity and kinematic viscosity, both at edge of undisturbed boundary layer, and distance from virtual origin of boundary layer, x		
S	frontal area of single rivet head (see Equations (3.3) to (3.5))	m ²	ft ²
u_τ	friction velocity, $(\tau_w/\rho_w)^{1/2}$	m/s	ft/s
δ	local boundary-layer thickness for which local velocity in boundary layer is 0.999 times local velocity at edge of boundary layer	m	ft
ν_w	kinematic viscosity at wall	m ² /s	ft ² /s
ρ_w	density at wall	kg/m ³	slug/ft ³
τ_w	wall shear stress	N/m ²	lbf/ft ²

2. SCOPE OF ITEM

The charts described in Section 3 provide a means of estimating the incremental drag coefficient of spherically-headed rivets. Figure 2, which applies only to low speeds ($M_1 \leq 0.5$), can be used for rivet heads with $h/d = 0.2, 0.3$ and 0.5 , whilst Figure 3 which contains data for higher Mach numbers, is applicable only to $h/d = 0.2$.

Issued April 1976 - 10 pages

The Item is based primarily on experimental data obtained at RAE Bedford (Derivation 2) for rivet heads on a flat wall (corresponding to a flat plate at zero incidence) with a turbulent boundary layer, and is applicable to airflow with zero heat transfer and zero pressure gradient. The rivet heads tested all had $h/d = 0.2$ but h was varied between 5.26 mm and 28.02 mm giving values of h/δ between 0.04 and 0.35. Tests were carried out at Mach numbers of 0.2, 0.8, 1.4 and 2.2. Low speed tests ($M_1 = 0.07$) on single rivet heads (Derivation 1) support the RAE data at $h/d = 0.2$ and provide additional data for h/d ratios of 0.3 and 0.5.



Sketch 2.1 Rivet geometry

For the RAE tests the rivet heads were mounted at a pitch of $2.5d$ in rows transverse to the airflow on a circular floating-element drag balance, of diameter 368 mm, set into the wind-tunnel wall. The rows were extended on either side of the balance plate so that the measurements represented the drag of rows of infinite extent. The exception to this was the largest rivet height (28.02 mm), which was tested as a single rivet head mounted centrally on the balance plate. For double rows of rivets the tests were limited to the smallest rivet height, the two rows being $2.5d$ apart and staggered by half the rivet pitch as shown in Sketch 2.1. The drag increment measured was the load on the rivets themselves, plus any changes in skin friction on the balance plate less the skin friction corresponding to the area covered by the rivet heads, but did not include the effect of drag changes induced downstream of the balance plate.

Table 8.1 summarises the ranges of experimental data used in the derivation of the methods given in this Item. Outside these ranges the methods may not give satisfactory estimates.