

LIMIT OF GRAIN SIZE FOR LAMINAR FLOW OVER WINGS OR BODIES

1. NOTATION

		<i>SI</i>	<i>British</i>
k	grain size	m	ft
l	characteristic length, wing chord or body length	m	ft
R	Reynolds number, Vl/ν		
s	distance of isolated grain from nose of wing or body measured parallel to chord line or body axis, respectively	m	ft
V	velocity of undisturbed air	m/s	ft/s
ν	kinematic viscosity	m ² /s	ft ² /s

2. NOTES

The limiting ratio of l/k above which transition is not affected is plotted in Figure 1 against R for uniformly distributed and isolated grains.

This Item refers to wings or bodies with partly laminar flow in the boundary layer. It is assumed that no other surface irregularities such as waviness or lap joints are present.

The curve for uniformly distributed grains is based on the simple hypothesis that the grains hasten transition only when their Reynolds number (based on the grain size and the velocity at the grain tip) exceeds the critical for which vortices are shed from the grain. Strictly this leads to the critical height increasing slowly with distance from the nose. The hypothesis does not take into account the effect of pressure gradient. It has been assumed as a first approximation that this effect nullifies the effect of distance from the nose.

The curves for isolated grains are based on the experimental values from tests on a typical laminar flow wing section. The effect of variation of chordwise position of the grain is shown. Experiments indicate that the shape of the grain has little effect on the limiting size for laminar flow.

There is some doubt on the validity of the curves at points close to the nose, and they are not applicable when the surface excrescences are close to the normal transition point. (The curves should not be used to estimate the permissible height of long discontinuities such as lap joints perpendicular to the air stream direction, as these may give rise to laminar separation without causing transition.) The effects due to interference of isolated excrescences are not known and caution should be exercised when the distance between such points is less than three or four diameters.

In practice, the distributed grains on a surface will not be of uniform height; the height of the largest that occur with fair frequency should be taken in assessing whether limiting roughness has been exceeded. With isolated grains both the height and position must be considered.

3. DERIVATION

1. DURAND, W.F. (Editor) *Aerodynamic theory*, Vol. 3. Springer, Berlin, 1936.
2. YOUNG, A.D. Surface finish and performance. *Aircraft Engineering*, Vol. 11, pp. 339-348, September 1939.
3. GREGORY, N. WALKER, W.S. The effect on transition of isolated surface excrescences in the boundary layer. ARC Rep. 13436, 1950.
4. KEEBLE, T.S. ATKINS, P.B. The effect of excrescences on transition; some observations in the boundary layer on Williams Glas II profile. Australian Department of Supply, ARL Aerodynamics Note 101, 1951.

4. EXAMPLE

For a wing of 10 ft chord, at a velocity of 400 mph and a height of 15 000 ft in a standard atmosphere, find the limiting projection of a normally flush rivet head at 0.2 of the chord if the transition point is not to be affected ($\nu = 229.4 \times 10^{-6} \text{ ft}^2/\text{s}$).

$$\text{Reynolds number, } R = \frac{Vl}{\nu} = \frac{400 \times 1.467 \times 10}{229.4 \times 10^{-6}} = 25.6 \times 10^6.$$

From this Item for $s/l = 0.2$, $l/k = 2.35 \times 10^4$.

The limiting rivet projection at 0.2 chord is

$$\frac{10}{2.35} \times 10^{-4} = 4.3 \times 10^{-4} \text{ ft} = 5 \times 10^{-3} \text{ in.}$$