TECHNICAL AEROMODELING-III

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In Parts I and II, I have tried to introduce simultaneously some of the most important characteristics of air flow at very low and very high speeds in order to show that an understanding of the peculiarities of model aircraft can be helpful in the more sophisticated problems of the aircraft industry. All understanding of basic phenomena is aimed at giving us more performance for the time and money we can spend on a design, so this third article will also lead to practical advice on low-speed airfoil design.

For the sake of those who may not have the July-August *Soaring*, the following resumé is made:

1. Reynolds Number (RN) is related to the relative effect of inertia to viscous effects of the air flow, and is given approximately by:

   RN = 10,000 x v (mph) x L (ft)

   . . . where the length L may be any characteristic length such as the wing chord, distance from the leading-edge, boundary layer thickness, etc.
2. Mach Number (M) is the aircraft speed relative to the speed of a signal through the air.
3. The "boundary-layer" of retarded air which is stuck to all moving surfaces has two conditions: *laminar* and *turbulent*, as illustrated in Figure I.
4. The *transition* process from *laminar* type to *turbulent* type, as illustrated by the smoke pattern of a cigarette, is hastened by vibration, roughness or artificial turbulence.

The next important concept necessary to an appreciation of very low or high speed aerodynamics is that of *separation*, which we will see is closely related to conditions in the boundary layer. Here is another case where traditional aerodynamic theory has never been solved exactly enough to be able to predict the results, so much observation and experience must be substituted. Separated airflow exists when the streamline of air along a surface suddenly leaves the surface, whereupon a sharply defined line is formed across which there is the stream velocity on one side and nearly zero velocity on the other. Such a discontinuity in fluid flow is unstable and rapidly forms little waves and whirls, and subsequently either turbulent diffusion (as in cigarette smoke), or bigger whirls. (The so-called "vertex street" behind cylinders got its name from the regularly spaced alternating vertices shed by the cylinder, which looked like a tree-lined street!) It is easy to observe separation in the flow of cigarette smoke around your hand or a piece of paper, and in the flow of air around the windshield corner of a car. Notice that there is not a "hole" in the fluid; air is still there, but there is a sharp line along which the velocity changes from zero to the external flow velocity.

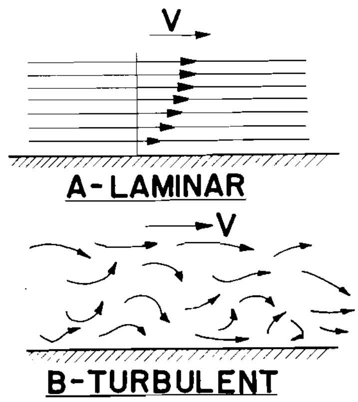

FIGURE - I
BOUNDARY LAYERS

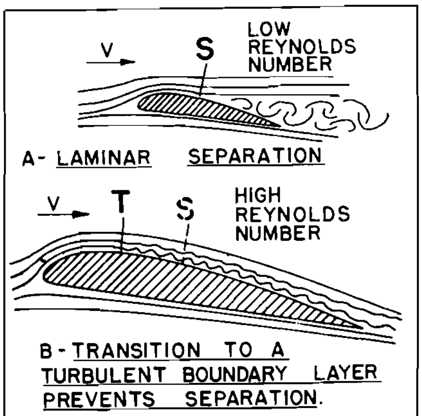

FIGURE- 2
EFFECT OF REYNOLDS NUMBER

Most of you have probably heard of the Bernoulli Principle, which says that the pressure on a surface in fluid flow is inversely proportional to the velocity-squared; that is, the higher the velocity, the lower the pressure (which we think of as "suction" usually). This is what sucks the juice out of a Flit sprayer; the high speed jet of air decreases the pressure at the top of the pipe and the fluid rises far enough to be blown away in a fine spray.

Of course, the resultant aerodynamic force or its components, lift, drag, etc., on a body moving in a fluid is simply the sum of all the local pressures from point to point over the body, which depend on the local velocities at these points, which in turn depend on the shape of the streamlines near the body. Since any separation affects the shape of the streamlines next to the body, separation has a direct effect on the resulting pressures and hence the forces. Without going into too much detail on this complex point, it can be said that *in nearly every case where there exists a separated region which is large relative to the body size, there will be less lift and more drag compared to the corresponding unseparated flow pattern about the same object.*

To improve performance of our aircraft, therefore, we must minimize the extent of separated flow, either by removing the causes of separation or by causing separated flow to re-attach in the shortest possible distance.

What are the causes of separation? A fundamental point of great importance must be remembered here: *Separation of flow from a surface can only occur where the flow is slowing down, i.e., the pressure along the surface is increasing (suction decreasing) with distance downstream.*

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