Recent Advances in Aerodynamics for Transport Aircraft

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The essential idea is to relate supersonic source distributions to a concept was first developed experimentally by R. T. Whitcomb in supersonic airplane configurations. The so-called area-rule con

The area-rule concept has for years been carried over into the high-speed subsonic regime without any rigorous theoretical or experimental basis. The basic idea is to compare area plots of
different configurations and form some conclusions about the probable drag-rise Mach number comparison on the basis of the maximum area and the related smoothness of the area distributions. When this approach is used as a means of selecting configuration geometry, it is called area ruling. The technique usually produces good experimental results, so the subsonic "area rule" has a certain usefulness as a smoothness and slenderness criterion that can lead to gains in drag-rise Mach number. This type of application is illustrated in Figure 25, which shows the basic 747 airplane and its associated area plot. An experimental investigation of an extension of the upper body (indicated by the dashed line) showed significant gains in drag-rise Mach number over the operating $C_L$ range with no essential change in drag level.

More recently, with rising interest in the near-sonic transport, the subsonic area rule was carried to the ultimate as a criterion and used to closely define the elements of the configuration, particularly the fuselage, to go along with the supercritical wing. This was done so as to yield a completely smooth area plot for the total configuration. It was also attempted to arrange the configuration elements so as to optimize the shape of the area plot and minimize the total cross-section area.

A typical result of this process is illustrated in Figure 26, which shows a near-sonic transport configuration and its associated area plot. The shape of the curve labelled "total equivalent area" is completely smooth, thus delaying the appearance of the so-called configuration shock and drag rise to near-sonic speeds. The actual area is somewhat smaller than the total equivalent area in the vicinity of the wing to provide compensation for wing lift.
The lift compensation principle in its original form was put forth by R. T. Whitcomb for application to configurations operating at near-sonic speeds. While the lift-compensation postulate was not analytically developed, the basic idea has been extended theoretically, and the experimental results have generally been quite favorable. This is illustrated in Figure 27, which compares the drag-rise characteristics of the wing-body combination of the near-sonic configuration shown previously with that of an axisymmetric body of equivalent area distribution and fineness ratio. The close agreement illustrates the applicability of the concepts used to evolve the near-sonic configuration. It is estimated that a similar application using the 747 wing would result in a substantial shift in drag-rise Mach number ($\Delta M \approx 0.05$) relative to the 747 configuration. Thus, the technique of area ruling, together with lift compensation, provides a significant advance in the technology of transonic aerodynamics.

We now turn to the streamline contouring concept, which appears to have originated independently in several centers of aerodynamic research in the 1950s, although in somewhat different forms. Independently conceived, its implementation and extension to a useful design concept was carried on at Boeing following this period. The essential idea is to use aerodynamic shapes for certain configuration elements (e.g., fuselage, nacelles, fairings, etc.) that conform to the streamlines calculated for the flow about the wing. The motivation for this is related to recognized limitations in the effectiveness of swept wings and, more fundamentally, to shortcomings in transonic aerodynamic theory and the whole process of configuration.