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3.2 Prospects and Time Tables for Analytical Estimation of the Drag of Complete Aircraft Configurations

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The estimation of the aerodynamic drag of a proposed subsonic aircraft configuration is still largely an art practiced with more or less skill by those called upon to perform it. For bodies such as fuselages and nacelles, one usually employs a correlation of wind tunnel and flight test drag data against finess ratio and surface area for generally similar bodies at low angles of attack as a basis for estimation. Wing and empennage profile drag are usually estimated from the rather extensive collection of airfoil test data which is now available. The drag due to lift can be determined in what may be called a semi-empirical fashion, that is to say, an adequate theory is usually simple enough to apply with perhaps some biasing here and there to make it agree better with experimental results. Interference effects, power effects, cooling losses, and protuberance drag are almost always obtained by extrapolation from previous experience.

The reason for following the aforementioned procedure is quite simple: It's the only one, one could realistically conceive of undertaking--until recently at least. Now, however, the situation is beginning to change. Largely, because of the capacity of the digital computer to carry out literally millions of calculations inexpensively in a short period of time, it is now possible to

1. Determine in a rigorous fashion from fundamental principles the lift, drag, and pitching moment of airfoils without concave surfaces at moderate angles of attack with good accuracy.
2. Determine reliably the lift, drag (profile as well as induced), and pitching moment distributions on moderate-to-high aspect ratio unswept wings or, alternately, the lift, pitching moment, and induced drag only of wings of arbitrary sweep and aspect ratio.
3. Determine with a fair degree of confidence the drag of quasi-streamlined bodies having a plane of symmetry, if the body is aligned with the stream.
4. Determine in some instances the interference effects of nacelles and fuselages on wing lift, or alternately the inviscid pressure distributions on simple, complete configurations.

Any of these four calcualtions can be done today in less than 15 minutes at a cost of less than $80.00. A more significant expense is frequently the preparation of an input data set to the computation program. For a fuselage some 1800 coordinates accurately representing the half-body and related so as to describe the body surface by quadrilaterals of nearly equal area are required.

The boundary layer routines used in these calculations are two-dimensional momentum integral types, although on simple axisymmetric bodies at zero angle of attack as well as airfoil problems, finite difference calculations are possible without exhorbitant additional cost or excessive computer storage requirements. The use of steady-flow, two-dimensional boundary layer model and its associated calculation techniques, however, make it difficult to locate the flow separation point accurately. Their use makes it almost impossible to determine the flow behavior in the separated wake (where the flow is almost invariably three-dimensional and unsteady). Flow models and calculation procedures to overcome these deficiencies are known but require computation times and computer storage two-to-three orders of magnitude larger than are presently practical for routine engineering analysis. As a result, completely analytical treatments of

1. the lift, drag, and pitching moment of bodies at angle of attack
2. the behavior of airfoils and wings near $C_{L_{max}}$ and beyond
3. flow separation due to interference
4. viscous flow over swept and low aspect ratio wings
5. turbulent onset flows containing a helical component and/or energetic streamwise component
6. disturbances produced by protuberances;

cannot be anticipated until the necessary computer hardware is available, estimated by Chapman (Ref. 1) to be about 1985.

There are, however, a number of developments known to be in progress which should reach fruition by the time the next generation of "number crunching" computers reaches the market, about 1977. Among these are

1. Improved singularity distribution techniques which permit the inviscid flow shield over bodies to be calculated with fewer but curved panels and which can give reliable results for bodies having concave surfaces.
2. Improvements on the Allen-Perkins method of estimating the forces on inclined bodies of revolution wherein the "inviscid" portion of the flow is to be calculated from a distribution of singularities.
3. Availability of three-dimensional boundary layer calculation routines for simple but non-axisymmetric bodies.
4. Availability of optimization algorithims linked to viscous flow field calculation schemes to permit one to specify the aerodynamic behavior

of bodies or wings desired and obtain the geometry which will provide it (Ref. 2). Later, this approach can be expanded to more complex configurations.

If progress in computer hardware continues as expected, then by about 1990 it should be possible to input a contemporary configuration, state some constraints as to performance, stability, and geometry, and the program will produce the geometric offsets for a modified configuration which will satisfy the stated constraints in an optimum fashion. Other programs could then be employed to produce the requisite structural configurations and to drive appropriate numerically-controlled manufacturing equipment. Whether these things come to pass will be dependent upon

1. The cost of developing the programs. Presumably this would be borne largely by the government.
2. The cost of running the programs. This is largely dependent upon the availability of hardware of the requisite speed and capacity.
3. The cost of engineering and technician labor to implement the programs or alternately, to do the computation task or parts of it manually.
4. The economic incentive to modify an existing aircraft or to build a new one for improved performance and stability with the same fuel consumption.

From this vantage point at least, one would estimate that a 10% increase in development cost could be tolerated if these procedures can yield a significant improvement (10%) in vehicle performance with the same power plant and with no degradation in handling qualities.

References

1. Chapman, Dean R., "Remarks presented at the NASA Conference on Aerodynamic Analysis," March 1975.
2. Hicks, R. M., and Vanderplaats, G. N., "Application of Numerical Optimization to Airfoil Design," NASA Conference on Aerodynamic Analysis. Also NASA TMX-3213, March 1975, 24 pp.