Canard-Wing Shape Optimization with Aerodynamic Requirements

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Abstract

THIS paper demonstrates a numerical technique for canard-wing shape optimization at two operating conditions. For purposes of simplicity, a mean surface wing paneling code[1] is employed for the aerodynamic calculations. The optimization procedures[2] are based on the method of feasible directions. The shape functions for describing thickness, camber, and twist are based on polynomial representations. The primary design requirements imposed restrictions on the canard and wing volumes and on the lift coefficients at the operating conditions. Results indicate that significant improvements in minimum drag and lift-to-drag ratio are possible with reasonable aircraft geometries. Calculations were done for supersonic speeds with Mach numbers ranging from 1 to 6. Planforms were mainly of a delta shape with aspect ratio of 1, with the canard and wing in the same plane.

Contents

The shape functions for the thickness,[3] and camber, and twist[4] were each expressed as a ten-term polynomial function of the Cartesian coordinates defined in the canard-wing plane. The coefficients of these polynomials had the status of optimization variables. Volumes of the wing and canard are constrained to specified values and correspond to the volumes of the base configuration in which both the canard and wing have 5% parabolic sections.

The study initially explored minimizing wave drag through wing-canard shaping by calculating the optimum thickness distribution with zero camber and twist. The results are shown in Fig. 1 for two canard sizes as well as for a wing-along case. Wave drag reductions of up to 50%, relative to the base configuration with constant thickness ratio airfoils, are feasible while still meeting canard-wing internal volume limits. The improvements in drag become more pronounced at high Mach numbers. The optimum shapes were found to be similar to those reported by Strand[3] for the wing-alone case, indicating that the presence of the canard does not introduce significant perturbations in the shape functions.

The second study explored the reduction in drag due to lift through optimization of the camber and twist of the lifting surface with zero thickness (Fig. 2). Again, results are shown for two canard sizes as well as for a wing-alone case. The configurations with subsonic leading edges show drag reductions of up to 36% by use of optimum camber and twist of the lifting surface. The potential for improvement tends to diminish with increasing Mach number in contrast with the results for the optimization of thickness. Figure 3 shows, in terms of L/D, the data of Fig. 2 and includes a simple flat-plate friction coefficient of 0.0025. Substantial improvements are obtained in this important parameter.

This was followed by an optimization of all the design parameters. The objective function to be minimized in this case is a linear combination of the drag coefficients at cruise and maneuver conditions,

$$f(X) = k_1 C_{D_1} + k_2 C_{D_2} \tag{1}$$

where k_1 and k_2 are the relative weighting factors specifying the relative importance of cruise and maneuver drag to the design mission. The drag coefficients C_{D_1} and C_{D_2} were calculated by the linear paneling technique from a knowledge of the thickness and of the camber and twist to satisfy the C_L requirements at cruise and maneuver. For reference, the wing and canard were optimized individually for cruise at $C_L = 0.3$

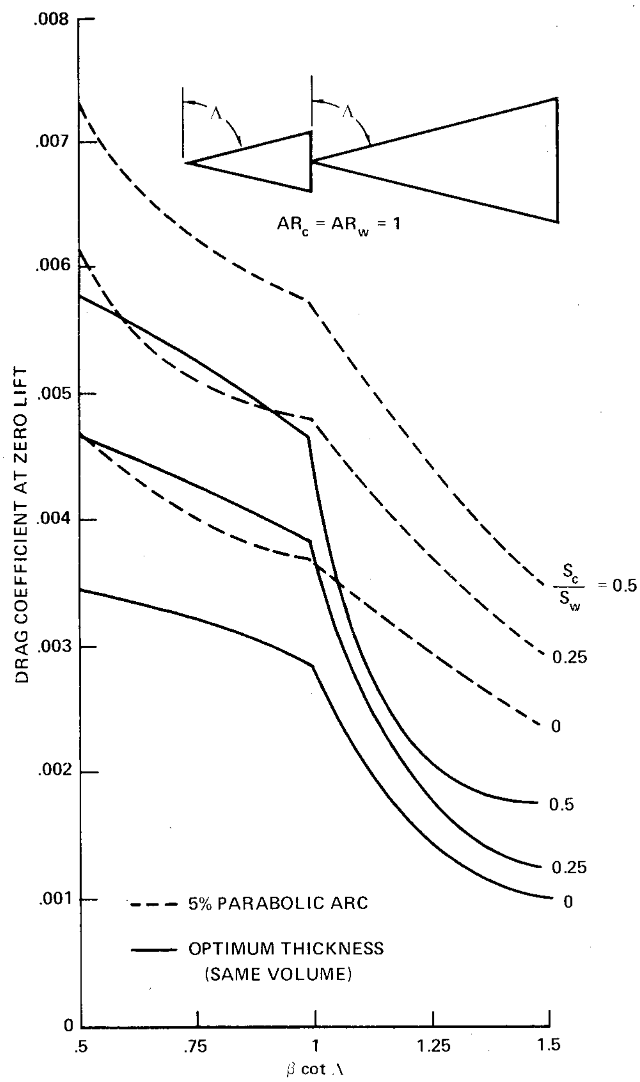

Fig. 1 Drag reduction by optimized thickness (no camber or twist).

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Index categories: Aerodynamics; Configration Design.

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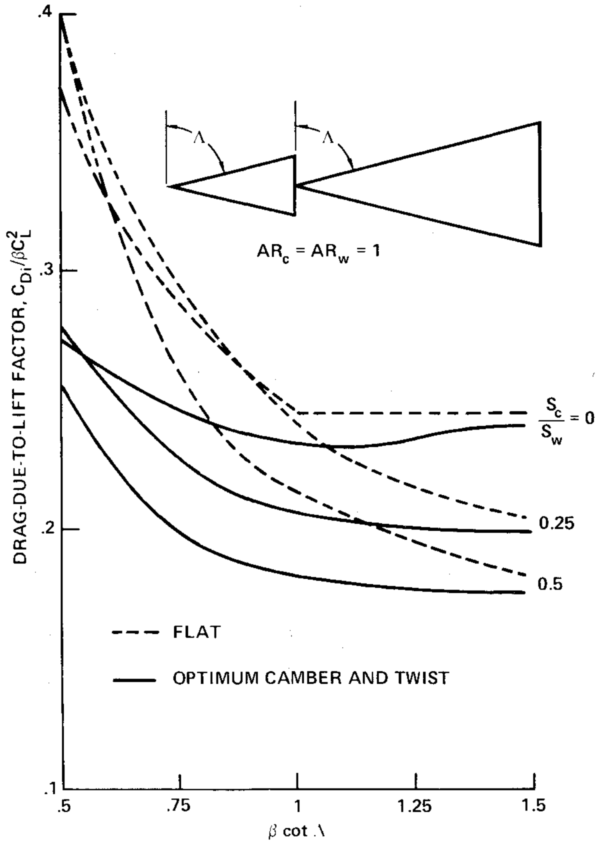

Fig. 2 Drag reduction by camber and twist (no thickness).

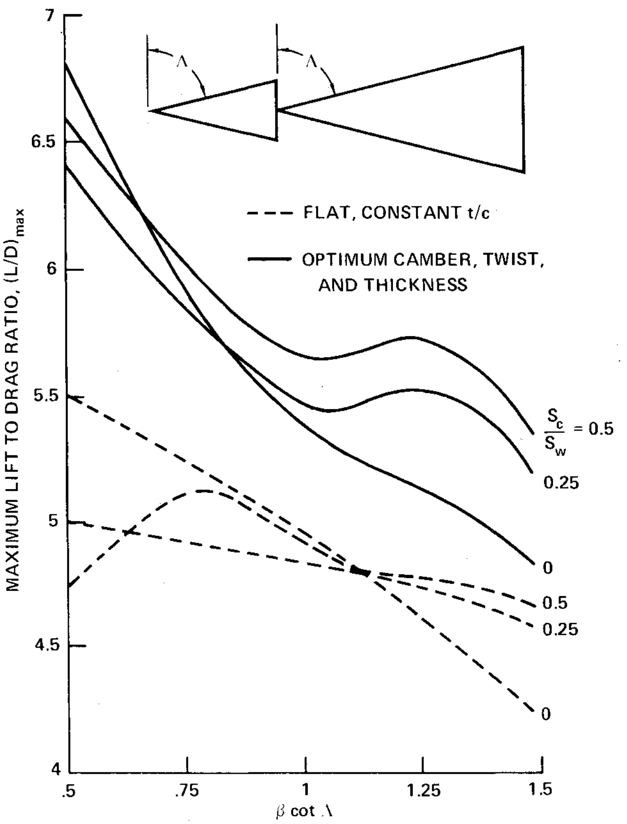

Fig. 3 Improvement in lift/drag.

at $M=1.6$ and for maneuver at $C_L=1$ at $M=1.6$. The resulting L/D curves are shown in Fig. 4. Next, the configuration was optimized to minimize the combined parameter $k_1 C_{D_1} + k_2 C_{D_2}$, where k_1 and k_2 were each

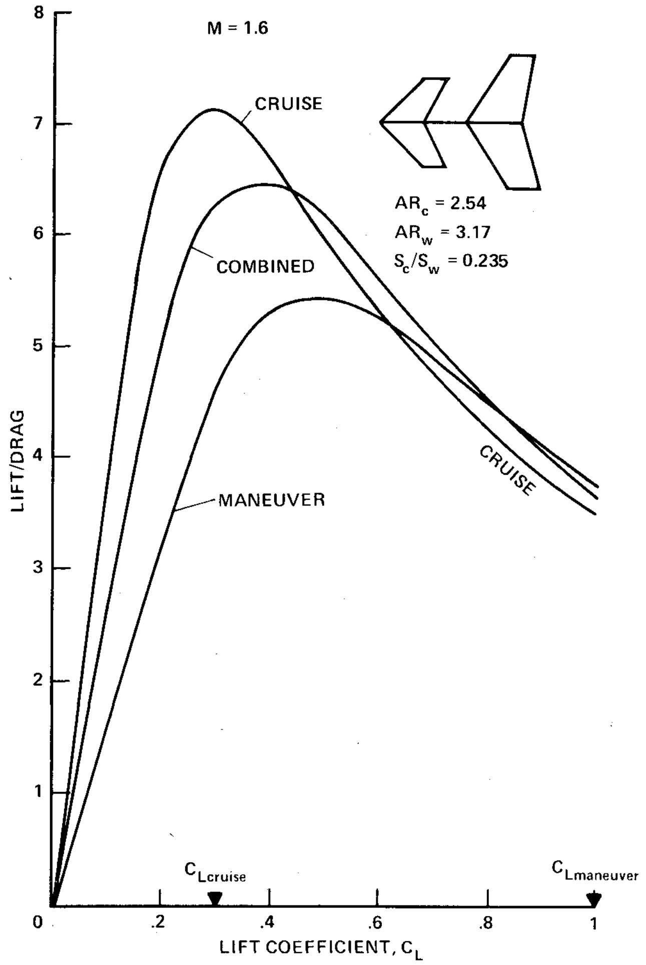

Fig. 4 Lift/drag optimized for combined cruise and maneuver conditions.

assumed to be 1.0. The resulting L/D curve is also shown in Fig. 4. By optimizing the combined parameter, a substantial improvement in the L/D at cruise is achieved with a very small penalty at maneuver.

The computer program was run on a CDC 7600 with typical run times of a few seconds for problems with up to 20 variables and 5-10 min for a 40-variable optimization. These run times were obtained with a simple aerodynamic code. If more sophisticated aerodynamic codes were used, the computer run times could be so large as to preclude a complete optimization study.

Conclusions

Significant gains in L/D can be achieved by proper shaping of the thickness and camber of wing-canard combinations. The computational methods can be applied to more general planforms without much effort, limited only by the aerodynamic procedures to account for more complex flow fields.

References

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