Engineering Notes

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Canard-Wing Interaction in Unsteady Supersonic Flow

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Introduction

TO develop a computer program on the basis of three-dimensional linearized theory for calculation of unsteady aerodynamic forces on a canard configuration in supersonic flow is a difficult task, and programs of this kind are not generally available. It may be of interest, therefore, to describe an approximate but simple method that was tried in the 1960's for the SAAB 37 Viggen (the first canard military airplane) and to compare results from this method with those from new programs for general configurations.

Programs intended to be applicable for canard configurtions have been developed by Chen and Liu[1] and Hounjet[2] on the basis of the doublet superposition principle. Results from two versions called SPNLRI-PG and SPNLRI-CP of the program developed by Hounjet will be used here for comparison. The PG version is similar to the potential gradient program of Chen and Liu,[1] whereas the CP version,[3] like Appa's method,[4] employs constant-pressure panels. This improvement extends the applicability to higher reduced frequencies.

The simple approximate method described here has not previously been published. It is utilized in an extended version of the so-called CHB (Characteristic Box) program, which is based on the source superposition principle. In this program, the special allowance introduced by Stark[5] for the source singularity at a subsonic leading edge is used, and the surface integral involved is evaluated by using small surface elements formed by characteristic lines. In the extended version for a canard configuration, the canard and its wake are treated as a slender configuration. This implies that the velocity due to the potential jump is calculated at points in crossflow planes by a routine based on two-dimensional theory.

Since there is no upstream influence in supersonic flow, the potential jump across the canard and its wake can be calculated by the CHB program without regard to the presence of the main wing. The normal velocity that corresponds to the potential jump across the wake is calculated by the approximate method and subtracted from the given normal velocity of the main wing. This result is then used as an input to a calculation by the CHB program for the main wing. The location of the canard wake above the main wing is determined experimentally or by a calculation for steady flow. The extended CHB program is included in the so-called AEREL system used at SAAB for flutter and response analysis.

The two-dimensional routine for modification of the given normal velocity of the main wing utilizes a linear combination of Chebyshev functions, fitted by the method of least squares to the previously calculated numerical values of the potential jump across the wake of the canard. The Chebyshev functions are defined by the imaginary part of the complex functions

$$F_n(Z) = [Z - (Z^2 - c^2)^{1/2}]^n \qquad n = 1, 2, \ldots$$

and the corresponding normal velocities by the real part of the derivative

$$\mathrm{d}F_n(Z)/\mathrm{d}Z = -nF_n(Z)/(Z^2 - c^2)^{1/2} \qquad n = 1, 2, \ldots$$

The semispan of the canard is c. The real part and the imaginary part of the complex variable Z are the spanwise and vertical coordinates respectively, of the point where the normal velocity shall be calculated.

The wing configuration to which the extended CHB program and Hounjet's two program versions have been applied consists of four trapezoidal wing panels with corner coordinates as follows:

x	y	z
0.7	+/−0.6	0.
0.6	+/−0.6	0.
0.	0.	0.
0.7	0.	0.
2.1	+/−1.2	−0.1
1.9	+/−1.2	−0.1
0.7	0.	−0.1
2.1	0.	−0.1

Two simple rigid-body modes are considered here. In the first mode, the canard is at rest, while the main wing is oscillating

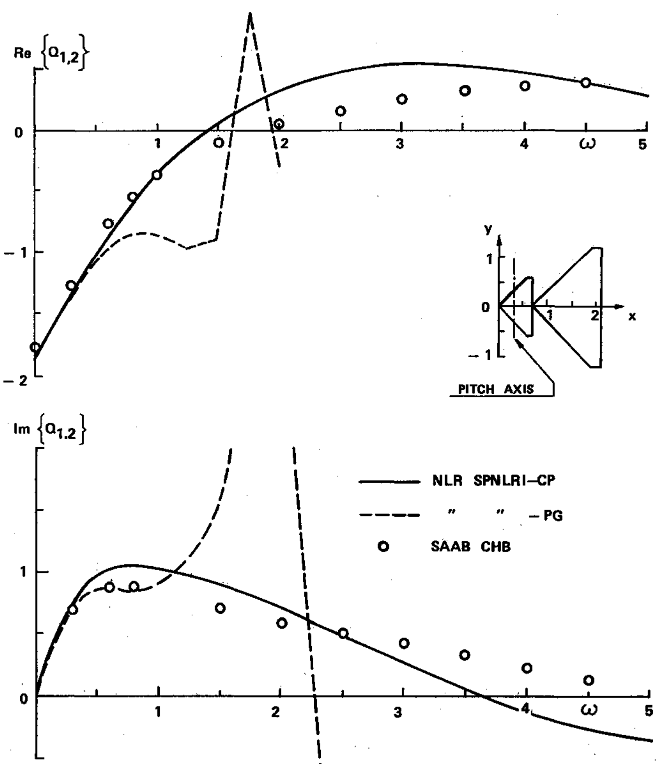

Fig. 1 Real and imaginary part of transfer function for lift on the main wing due to pitch of the canard, $M = 1.054$.

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in vertical translation. In the second mode, the canard is pitching about $x = 0.35$ (see Fig. 1) with unit amplitude 1 radiant, while the main wing is at rest.

The results for the real and imaginary parts of the dimensionless transfer function $Q_{1,2}(i\omega)$, which represents the lift on the main wing due to pitch of the canard, are shown in Fig. 1. The transfer function, which is referenced to the dynamic pressure and a reference area equal to the square of the semispan of the main wing, was calculated for a Mach number of 1.054 and several values of the reduced frequency ω (referenced to the unit of length).

Comparing the results for $Q_{1,2}$ from the extended CHB program and the SPNLRI programs, we observe a slight difference for $\omega = 0$. If this difference is corrected, which may be achieved by changing the grids slightly, the results from all three programs would agree very well up to a reduced frequency of about 0.6.

For greater reduced frequencies, the SPNLRI-PG program becomes inapplicable, which apparently is due to the increasing difficulty of evaluating the integrals involved.

For $\omega = 5$, the wavelength of the variation of the potential jump across the wake of the canard in the streamwise direction is approximately equal to the root chord of the main wing. Consequently, it was not expected that the present simple method of allowing for the canard-wing interaction would yield accurate results in the upper part of the frequency range in Fig. 1. It is, therefore, a surprise that the deviation from the SPNLRI-CP result is not too great.

Considering the great difficulties involved in the development of programs for general configurations in supersonic flow, it was thought that this brief account of a simple method would be of interest.

Acknowledgment

Results from the two versions of the Hounjet program were kindly supplied by NLR.

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