Prediction of Vortex Lift on Interacting Delta Wings in Incompressible Flow

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Abstract

VORTEX flow modeling is used to calculate the steady inviscid incompressible flow past a three delta wing configuration, which is an idealized model of the lifting components of the Spacejet concept for a possible future space transportation system The wings are modeled with vortex lattices and the leading and trailing edge sheets are modeled by segmented straight vortex filaments Aero dynamic characteristics are obtained for a range of geometry and angle of attack

Contents

The physical model for the current theoretical investigation is the Spacejet as described in Small, Riebe, and Taylor [1] An idealized model of the lifting components of the Spacejet consists of a main delta wing with two smaller delta wing boosters mounted underneath Each wing is sharp edged and develops nonlinear vortex lift from leading edge separation The idealized model has been tested at the U S Military Academy by Faery, Strozier and Ham [2] who also obtained numerical estimates for the lift using the vortex lattice suction analogy approach of Lamar and Gloss[3] and Margason and Lamar [4]

In recent years, many numerical techniques have been developed to predict the detailed aerodynamic characteristics of lifting surfaces with leading and/or side edge separation in steady incompressible inviscid flow Two excellent reviews are given in Hoeijmakers[5] and Lamar and Campbell [6] The development of nonlinear discrete vortex or vortex lattice methods (see for example, Kandil Mook and Nayfeh[7]) allowed for the computation of fully three dimensional flowfields without the use of slender wing and conical flow assumptions For the interaction problem, it is necessary to model three wings with their associated vortex sheets The choice was made to use a discrete vortex method instead of a more accurate higher order panel approach in order to keep the computer storage and run time requirements of the research at a manageable level

The panel arrangement and vortex lattice used in this Study differ in many respects from those used by other in vestigators; therefore, it is important to document the results for the main wing alone case The USMA experiments[2] consider equilateral 60 deg delta wings (aspect ratio of $4/3^{1/2}$) This value of aspect ratio will be emphasized in what follows

For the chosen panel layout, extensive numerical studies were performed to determine the choice of parameters to provide the optimum convergence characteristics for the method The major difference between the current model and those in the literature is that here the bound vortex segments are placed at the panel half chord instead of at the traditional location, the quarter chord The panel control point is still at the three quarter chord point

The numerical method was validated by obtaining calculations for the main wing alone case for several examples previously studied both numerically and experimentally Excellent agreement for the lift coefficient was found over a wide range of aspect ratio and angle of attack The lift variation with angle of attack for the equilateral 60 deg delta wing is compared in Fig 1 for the numerical method (60 wing panels) and the experiments of Ref 2 and Refs 8 10 It is noted that the USMA experiments[2] are on the average, 6% higher compared to the other experimental results The calculations are performed on the University of Maryland Computer Science Center's Univac 1180 The run times in minutes for 18, 36, 60, and 90 panels on the wing are 10 40, 70, and 240 respectively

Calculations were made for the booster wings alone (two wings side by side with tips touching) case which was studied experimentally in Ref 2 Comparisons for the lift coefficient (18 panels on each wing) are shown in Fig 2 and the ex perimental data observation is duplicated with the theory Note that for higher angles of attack, vortex breakdown occurs and the measured vortex lift decreases (The present model does not account for vortex breakdown)

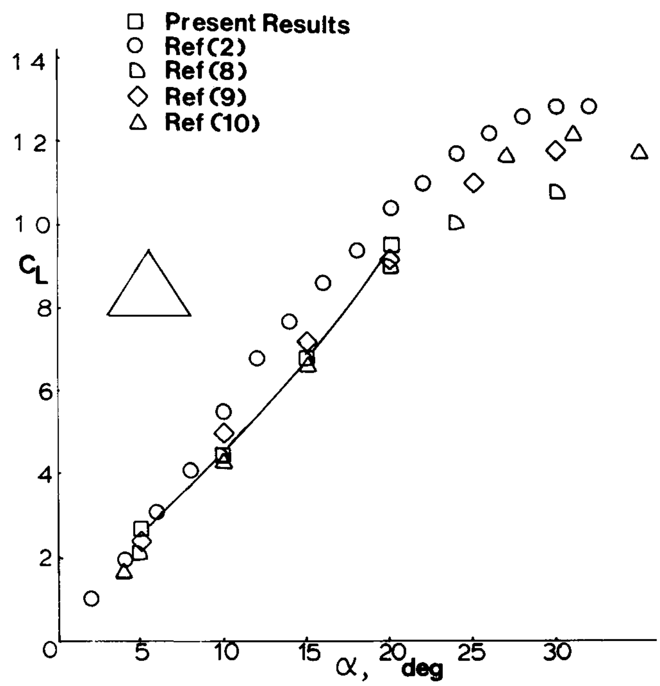

Fig 1 Experimental and theoretical lift variation for single delta wing

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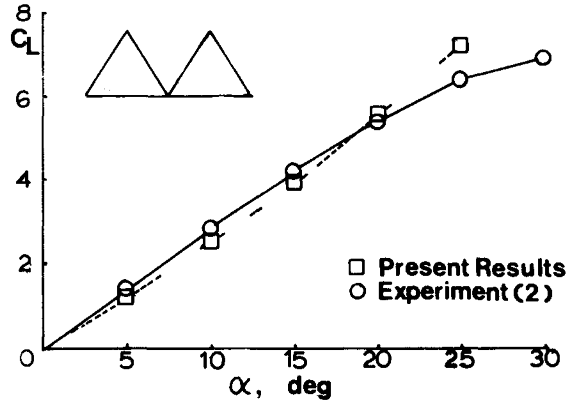

Fig 2 Experimental and theoretical lift variation for booster wings alone (tips touching)

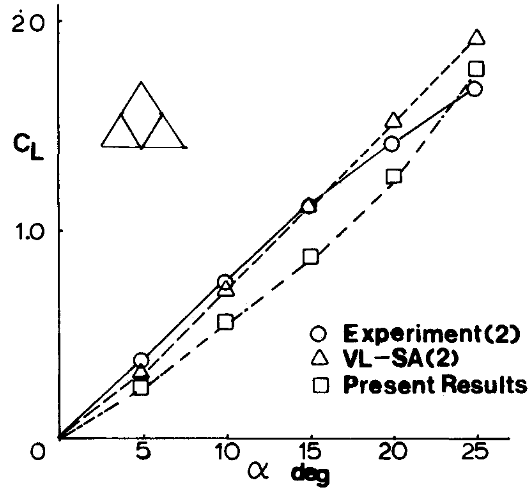

Fig 3 Experimental and theoretical lift variation for three wing configuration (vertical separation of 0 444 main wing root chords).

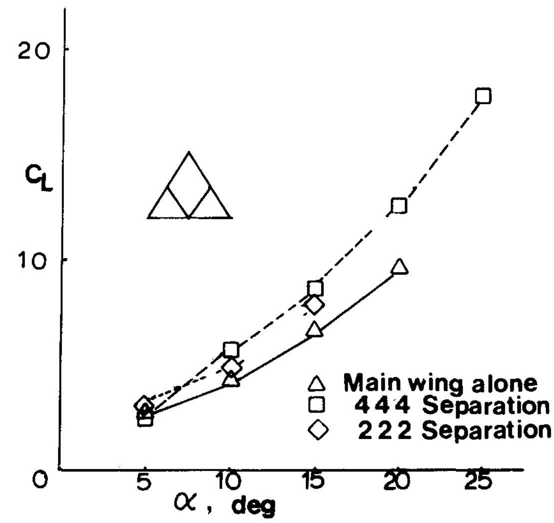

Fig 4 Theoretical lift variation for three wing configuration for two values of vertical separation

Calculations were made for the complete three wing configuration It is stated in Ref 2 that the vertical separation between the main wing and boosters is the geometric parameter which affects the aerodynamic characteristics most significantly The effect of the variation of the vertical separation was studied for boosters with tips touching, trailing edges lining up with the main wing trailing edge and total span equal to the span of the main wing The lift coefficient results for a nondimensional vertical separation of 0 444 based on the main wing root chord are compared to the experimental and vortex lattice suction analogy results from Ref 2 in Fig 3 There are 18 panels on each wing and the run time (for 6 iterations) was 54 minutes It is seen that the present calculations are below the other results throughout the angle of-attack range (until vortex breakdown occurs)

The major experimental result in Ref 2 is the determination that the aerodynamic interference between the main wing and boosters is unfavorable and that the vertical separation should be made as large as possible In Fig 4, the computed lift coefficient is shown for nondimensional separation distances of 0 222 and 0 444 The results for the main wing alone are also presented The trend of the experimental results is duplicated

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