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Reply by Author to J. L. Hess

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DR. Hess is correct in pointing out that the data shown in Fig. 14 of Ref. 1, labeled as Hess Program results, were obtained using the method of Ref. 2 rather than that of Ref. 3. This author appreciates this correction and apologizes for any wrong impression that might have been created about the accuracy of the Hess' higher order method of Ref. 3.

Nevertheless, the basic message of the discussion involving Fig. 14 in Ref. 1 remains unchanged: namely, a properly implemented low-order, constant singularity strength panel method should yield subsonic flow results of an accuracy comparable to that of the higher order panel methods but at a fraction of the computational effort.

The argument of comparable accuracy is clearly demonstrated in Fig. 1, which is the same as Fig. 14 of Ref. 1 but with the results of Hess' higher order method of Ref. 3 included. These latter results were obtained from Fig. 1 of Hess' Technical Comment. Both of Hess' computations, i.e., first order and higher order, used 9×36 panels (9 circumferentially and 36 longitudinally), whereas the QUADPAN (Lockheed's advanced low-order panel method) computations were carried out with 8×36 panels.

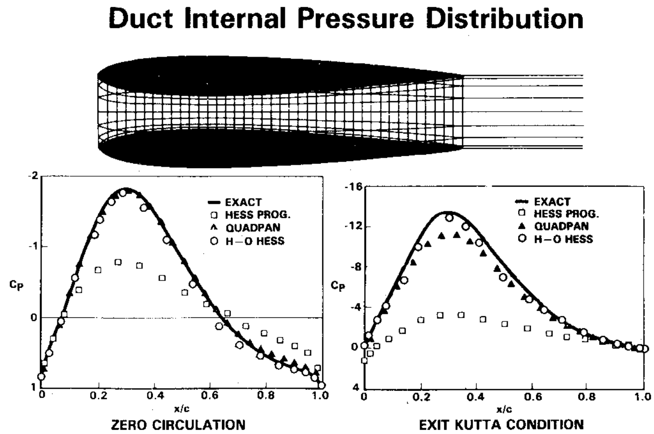

Fig. 1 Comparison of theoretical results for nacelle internal flow.

The question of computational effort cannot be directly addressed in this particular case because this author has no cost data for Hess' higher order computations. An examination of the two major contributions to the computational cost of any panel method may help answer this question. One of the major costs stems from the solution to the linear system of equations. Since Hess' higher order method uses only one control point per panel, both it and QUADPAN will generate essentially the same size linear system for the same number of panels. Therefore, assuming comparable solution techniques, the contribution to the cost from the matrix solution should be the same from either method. The second major cost contributor is the generation of the linear system. This includes the calculation of the influence coefficients and the distribution of these coefficients into a matrix. Both of these operations are more complex for Hess' method than for QUADPAN, involving higher order terms in the influence coefficients and local least-squares splines for source continuity. Consequently, other things being equal, a higher computational cost should be incurred when using Hess' higher order panel method.

Other higher order approaches to panel methods, such as PANAIR,[4] generate significantly larger linear systems of equations for the same number of panels. Thus, in addition to a more expensive computation of influence coefficients, there is a much greater effort required to solve for the singularity strengths. This type of panel method will fare much less favorably than Hess' method when compared to an advanced low-order panel method like QUADPAN.

Even though it may be more a matter of semantics rather than substance, it should be pointed out that the older Hess' method of Ref. 2 is, in a sense, a method of higher order than QUADPAN. Although both have the same order source distribution, namely, constant or zeroth-order, the constant vorticity distribution used in Hess' method is equivalent to a linear (first-order) dipole distribution, whereas QUADPAN uses a constant (zeroth-order) dipole distribution.

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