Technical Comments

Comment on "PAN AIR Applications to Aero-Propulsion Integration"

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RECENTLY Chen and Tinoco[1] applied Boeing's PAN AIR potential flow solver to several problem areas in propulsion modeling in engine and airframe integration PAN AIR's success in linearized subsonic and supersonic un powered potential flows past complex configurations has set industry standards and undoubtedly will continue to do so However, as described, its application to powered flows is basically unsound, representing methodology at least a decade old It is known, for example, that, 1) the internal exhaust plume flow is rotational and not amenable to any potential modeling, the engine turbomachinery having imparted to the downstream flow radially varying work[2] and, 2) even for assumed radially uniform increases in total pressure, two potentials rather than one are needed, along with appropriate actuator disk and trailing slipstream matching conditions [3 4]

To simulate power effects, exhaust plumes are modeled as wakes or solid surfaces with or without transpiration; plume surface shapes are "usually derived from a more complete axisymmetric calculation " while required values of tran spiration are "found by trial and error for an isolated case" using experimental data or Navier Stokes results This completely nonpredictive approach, unfortunately, gives only the illusion of solution Not only does Ref 1 fail in addressing realistic power simulations, as would be suggested in its Abstract, but use of any isolated axisymmetric core model is probably irrelevant to installed three dimensional flows given typically strong mutual interference effects Agreement with empirical data, in any case, is fortuitous and misleading

In fact, the problem cited in item 1 above was treated rigorously in Ref 2 Using invariant properties of vorticity it was shown how small disturbances to radial velocity shears, imparted just downstream of an internal actuator disk, say, with streamwise speed $U(r)$, satisfy $\phi^*_{xx}+\phi^*_{rr}+(1/r-2U\ /U)\phi^*_r=0$ exactly, $\phi^*(x,r)$ being a "super potential " This simple modification is easily implemented numerically The new equation then was solved along with the potential equation for the external flow for an isolated axisymmetric nacelle for several power settings (if three dimensional effects are indeed weak the ϕ^* equation with a parametric "θ" dependence holds for installed flows) On the other hand, Refs 3 and 4 deal extensively with problem 2 above Special wake potential jump boundary conditions were derived, again rigorously showing how only simple code changes are required, to realistically simulate power addition; these changes, applicable as well to fully three dimensional and transonic supercritical flows render unncessary the overly limiting assumptions made in Ref 1

It is unfortunate that the engine power simulation methods undertaken at Boeing as described in Ref 1 and other related literature have not progressed beyond 1960's technology; and perhaps more so, because the resulting PAN AIR software originally developed at great cost and labor, is only as good as its least accurate part The "versatility" claimed by the authors does not exist at least in the predictive sense but it is attainable following the approaches outlined in Refs 2 4 Computational methods we must understand, become mere graphics exercises when ad hoc formulations replace physical and mathematical judgment

Received March 28 1984
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Reply by Authors to W.C. Chin

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CHIN seems to have missed the main point of Ref 1 The problem of aero propulsion integration obviously requires the prediction of three dimensional flows about complex geometries Since the technology to solve the Navier Stokes equations for complex geometries is not available at this time, and probably will not be available for years to come, various simplified approaches need to be taken In addition to the panel method used in Ref 1, the Boeing Company also uses finite difference transonic methods[2] and Euler equation solvers,[3 4] and has been working toward joining panel method and Navier Stokes solvers [5] Reference 2 presents results on wing/body/strut/nacelle configurations using surface transpiration to simulate the power effect Reference 3 treats isolated powered nacelles of arbitrary geometry while Ref 4 treats wing/body/nacelle/propeller configurations Work is underway to add the strut Reference 1 was an effort to demonstrate the use of practical engineering tools Although Ref 1 showed only one example, the method has been applied to numerous configurations with equal success It may represent a methodology at least a decade old, but it works well

References

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Received May 7 1984
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