N87-22799

DEVELOPMENT OF AN INTEGRATED BEM FOR HOT FLUID-STRUCTURE INTERACTION

G.F. Dargush and P.K. Banerjee
State University of New York at Buffalo
Buffalo, New York

The design of hot-section components such as those in SSME is generally accomplished by examining the solid and the fluid individually. Typically, the analysis that is required to support the design process is performed by separate groups using different techniques and computer codes. For a solid, a two-step approach is undertaken, a thermal analysis to determine the temperature profile using either a finite difference or a finite element method and the subsequent stress analysis by finite element method.

The finite element method for stress analysis has reached a very high level of maturity and sophistication. Principal codes have comprehensive facilities for material and geometric nonlinearities, inhomogeneity, anistropy, as well as considerable flexibility, in the specification of boundary conditions. A similar development of boundary element is well on the way as a part of the host program and has already proven to be extremely attractive and cost effective for both linear and nonlinear stress analyses problems.

Computational fluid dynamics is, however, at a much less developed stage. The governing equations are highly nonlinear and coupled. Finite difference method dominates the scene primarily due to its simplicity and consequently one has to pay a price for this simplicity. Extremely dense grids are required near boundary and in regions of high velocity gradients. Varying requirements of discretization in the flow field, boundary layer, etc. can often lead to stability and accuracy problems. Finite element methods have also been applied recently, but it also suffers from the same restrictions.

There is therefore a need to examine an alternative approach that considers the fluid flow and the solid deformation as a coupled problem using boundary element method. Since this method uses boundary equations, it would be easier to develop a coupled analysis and since the nonlinearities in the fluid are primarily confined to regions, it may be possible to develop an efficient and cost effective solution.

METHOD OF ANALYSIS

Because the problem is essentially a coupled one, any separate treatment of each part (fluid and solid) would require the introduction of a complex set of artificially devised boundary conditions at the common interface to take care of the complex flow and heat transfer phenomenon. The problem is schematically depicted in Figure 1, where the solid region is subjected to pressure (p), temperature (T) resulting in displacements (u) and stresses. The flow of fluid from both inside the solid and outside is governed by the velocity (v), pressure (p) and temperature (T) as well as the boundary displacement (u).

A boundary integral representation for the entire coupled problem has been recently completed. The formulation is based on the fundamental analytical solution of the Navier-Stokes equation for the fluid velocity in an infinite domain. This fundamental solution was obtained by decomposing the Navier-Stokes equation into vorticity and dilation transport equations. A boundary integral formulation involving convolutions in time was then constructed in which the convective terms appear in the volume integral.

The entire fluid formulation has been implemented and the linear part of the viscous flow is already giving good results. It is hoped to get some nonlinear flow problems working within the next few months. Figure 2 shows 4 boundary elements and 1 cell representation for the couette flow problem and Figure 3 shows that the exact analytical solution is reproduced by such a simple discretization. It is therefore likely that viscous flow at a high Reynolds number could be efficiently solved by this method.

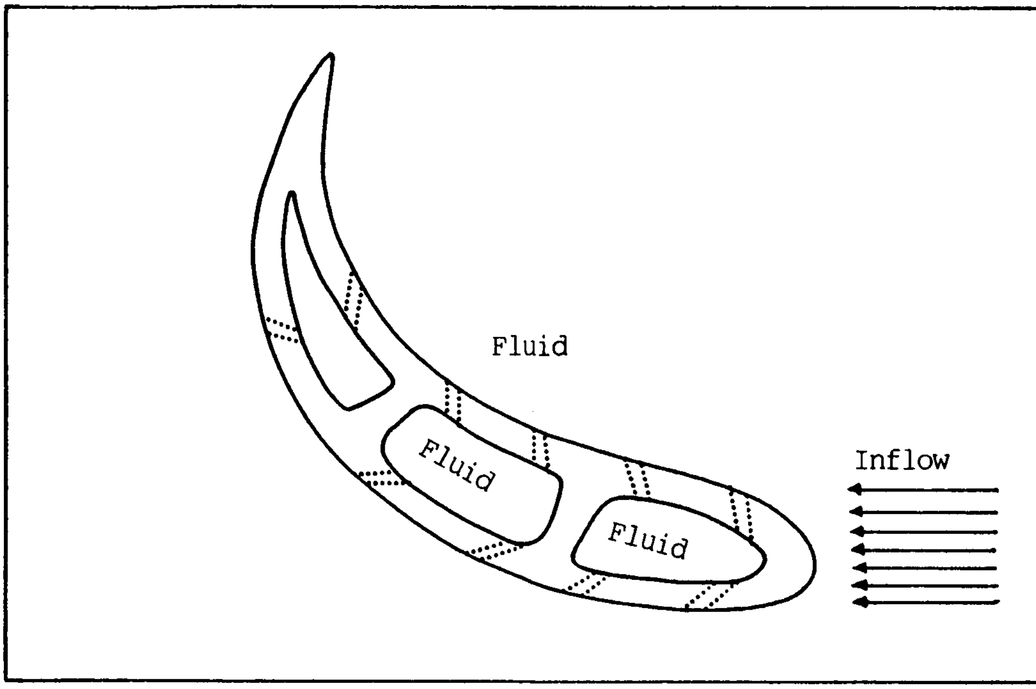

FIGURE 1

HOT FLUID STRUCTURE INTERACTION

BOUNDARY ELEMENT MESH

COUETTE FLOW

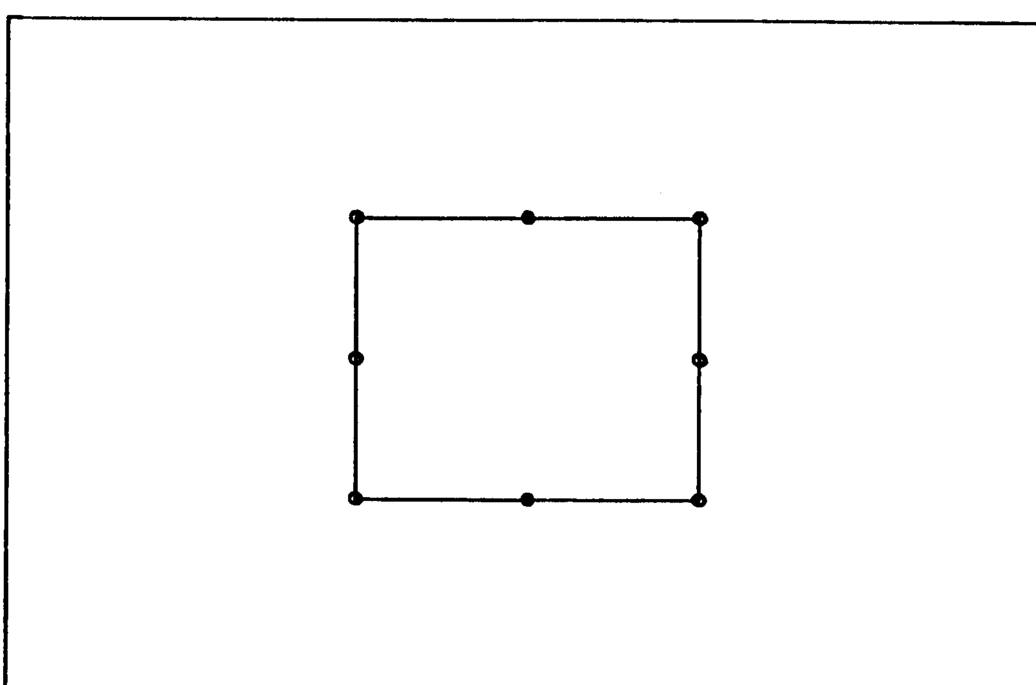

FIGURE 2

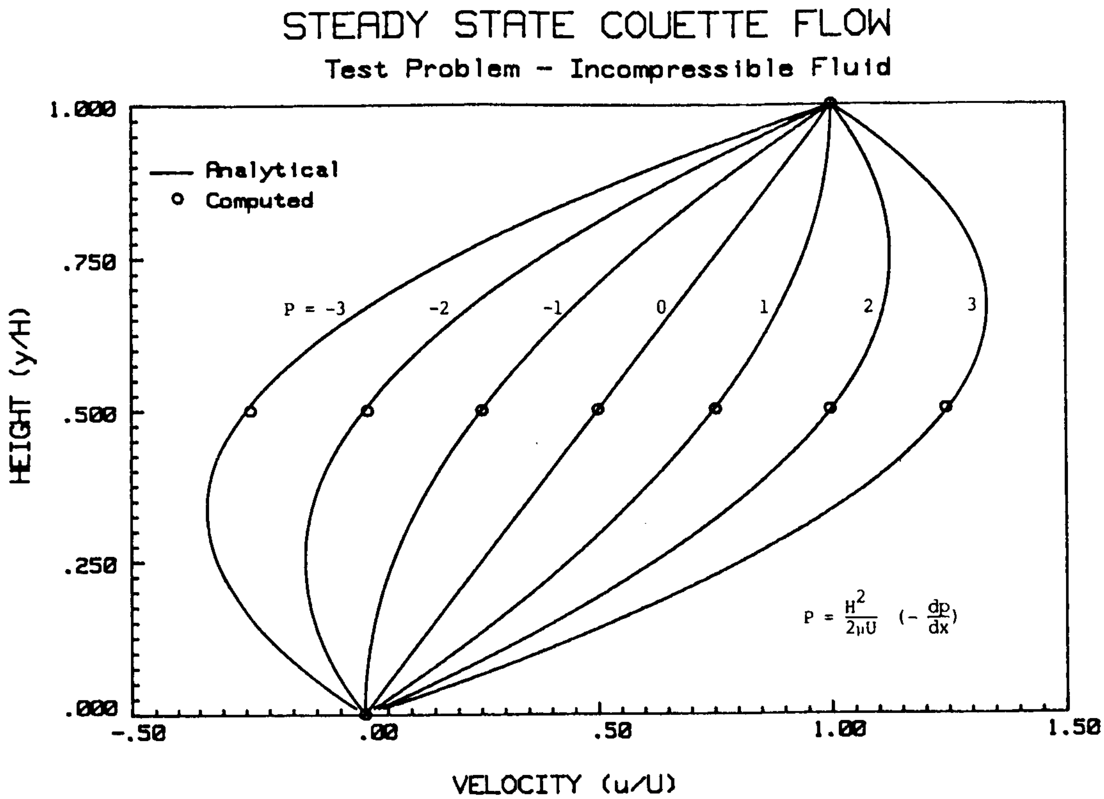
STEADY STATE COUETTE FLOW
Test Problem - Incompressible Fluid
Analytical
Computed
HEIGHT (y/H)
VELOCITY (u/U)
1.000
.750
.500
.250
.000
-.50
.00
.50
1.00
1.50
P = -3
-2
-1
0
1
2
3

FIGURE 3