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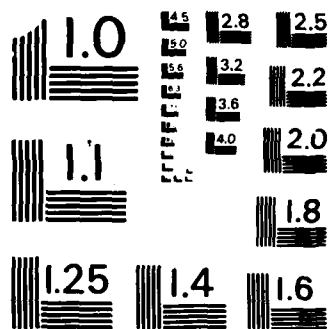
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Final Report of ONR Grant NR062-773
(N00014-84-K-0454)

June 1984 - September 1985

Computation of Ship Waves

Prof. John C. Strikwerda
University of Wisconsin Madison

Prof. James F. Geer
State University of New York Binghamton

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The research covered by this grant was directed toward developing a numerical method for computing wave drag on ship hulls of general shape. The research as originally proposed was to extend for three years, however only fifteen months of research were supported. In this time the soundness of the program of research as presented in the original proposal has been demonstrated and several objectives were met. The numerical method has been tested on several fluid flow problems and its accuracy and efficiency have been demonstrated. The wave drag has been studied on a simplified model of a ship, one lacking a bow and stern, and it has been found that the drag is qualitatively the same as that of a real hull shape.

The basic numerical method is applicable to a wide class of problems involving a free surface associated with potential flow. The calculation of ship waves is one of the more difficult applications; less difficult applications are the calculation of the time evolution of two dimensional surface waves and the calculation of waves in a slender channel of varying cross section. Periodic two dimensional surface waves have been studied quite extensively using analytical techniques and thus provided tests for the accuracy of the numerical methods. Tests were made for a wide range of wave length, height, and depth of the fluid and excellent agreement was achieved. These results are published in the thesis of Prof. Asaithambi [1] whose doctoral work was supported in part by this grant.

The computation of steady three dimensional wave motion, such as for ship waves or flow in a narrow channel, relied on a perturbation expansion in the slenderness ratio. In the cases considered in this work, this gives rise to a system of nonlinear equations that can be solved as an initial value problem in the direction of flow. An implicit numerical method is used for marching in the flow direction and this results in a system of nonlinear equations to be solved. The efficiency of the numerical method is the result of using this implicit method and coupling this with the iterative solution of the equation for the potential and the iterative solution of the nonlinear equations.

The co principal investigator, Prof. Geer, concentrated his research efforts on the bow effects, with the aim of incorporating his work into the numerical solution algorithm. Due to the termination of the grant this integration of the two research efforts was not possible. Dr. Geer also contributed substantially in the choice of test problems for the method and in evaluating the results of the tests.

There remain several goals of the original proposal which have not been met. The nonattainment of these goals is due more to the shorter amount of time for the grant than originally planned than it is to defects in the research program itself. Chief among these

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goals are the development of grid methods to adequately handle the general hull shapes and the numerical computation of flow past the bow and stern of a hull.

The difficulty of achieving good resolution with the grid highlighted the need for better grid methods. In particular, it became apparent that more research is needed on the use of multiple grids with finite difference methods. Prof. Strikwerda will continue to do research on methods of using composite grid methods with elliptic systems of equations.

The attached figures 1, 2, and 3 show the wave pattern associated with different speeds for the simplified ship problem. The simplified ship model consists of a circular cylinder of infinite extent and with a small bulge over a finite portion of the cylinder. Wave drag is induced by the flow past this bulge. Figure 1 is for the lowest speed, measured by the nondimensional parameter ν^{-1} . Figures 2 and 3 are for faster flow speeds. Note that there is a distortion in the waves at the right and left computational boundaries due to non-physical reflections which ultimately dominate the solution. In each figure, the region shown is has a length equal to that of the bulge. The development of computational boundary conditions which are less reflecting was addressed in the original proposal, but was not undertaken because of insufficient time. Figure 4 displays the coefficient of resistance for the wave drag as a function of the Froude number for a slenderness ratio of 0.10.

There were no reports published as yet as a result of this research. Some of the research contained in the thesis [1] of Prof. Asaithambi, currently at Mississippi State University, may be published in the open literature. Prof. Asaithambi gave a talk, "The Computation of Waves in a Slender Channel of Varying Width," at the SIAM meeting in June 1985.

Reference

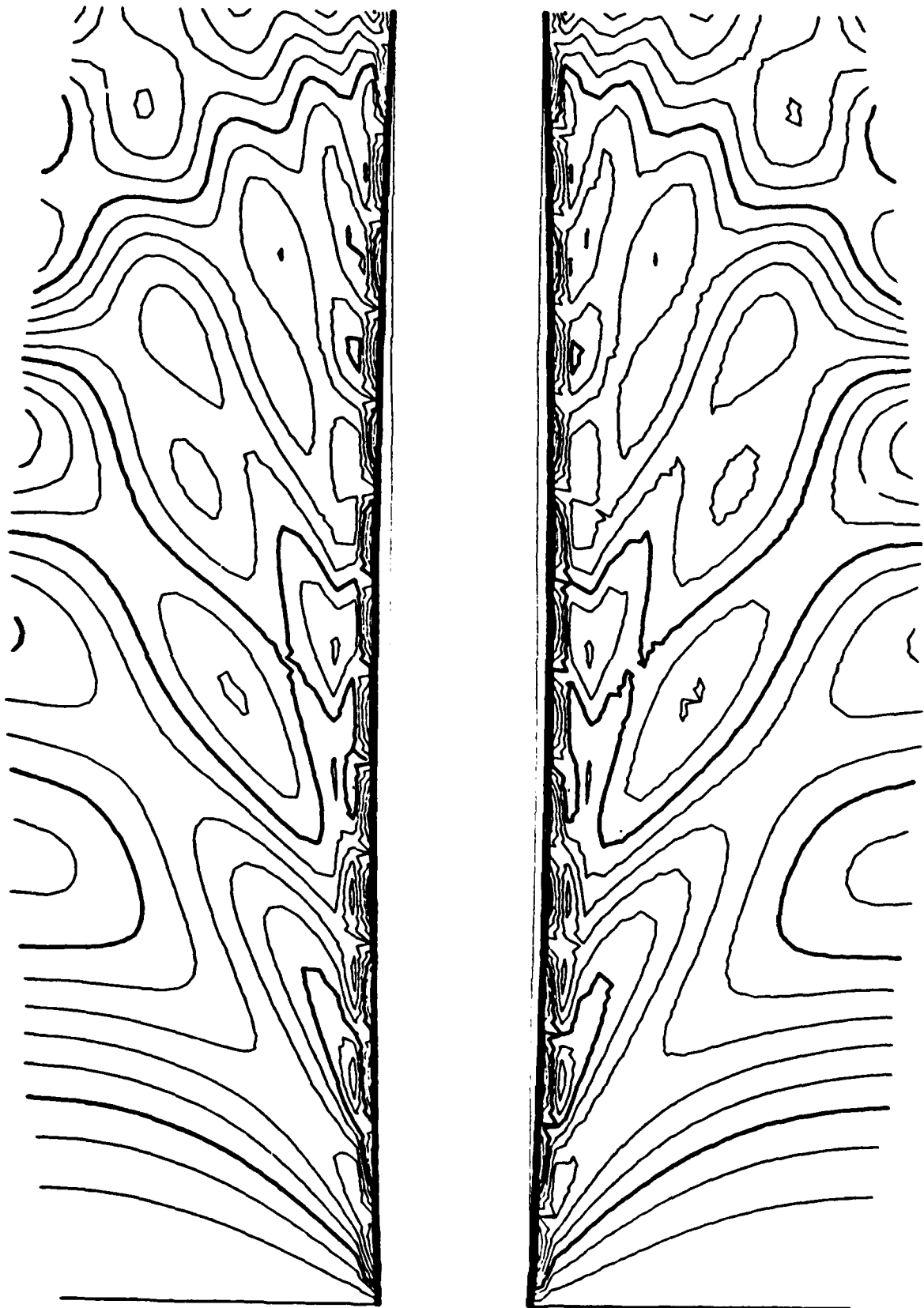
- [1] N.S. Asaithambi, A Numerical Method for Free Surface Flows, Thesis. University of Wisconsin Madison, 1985.



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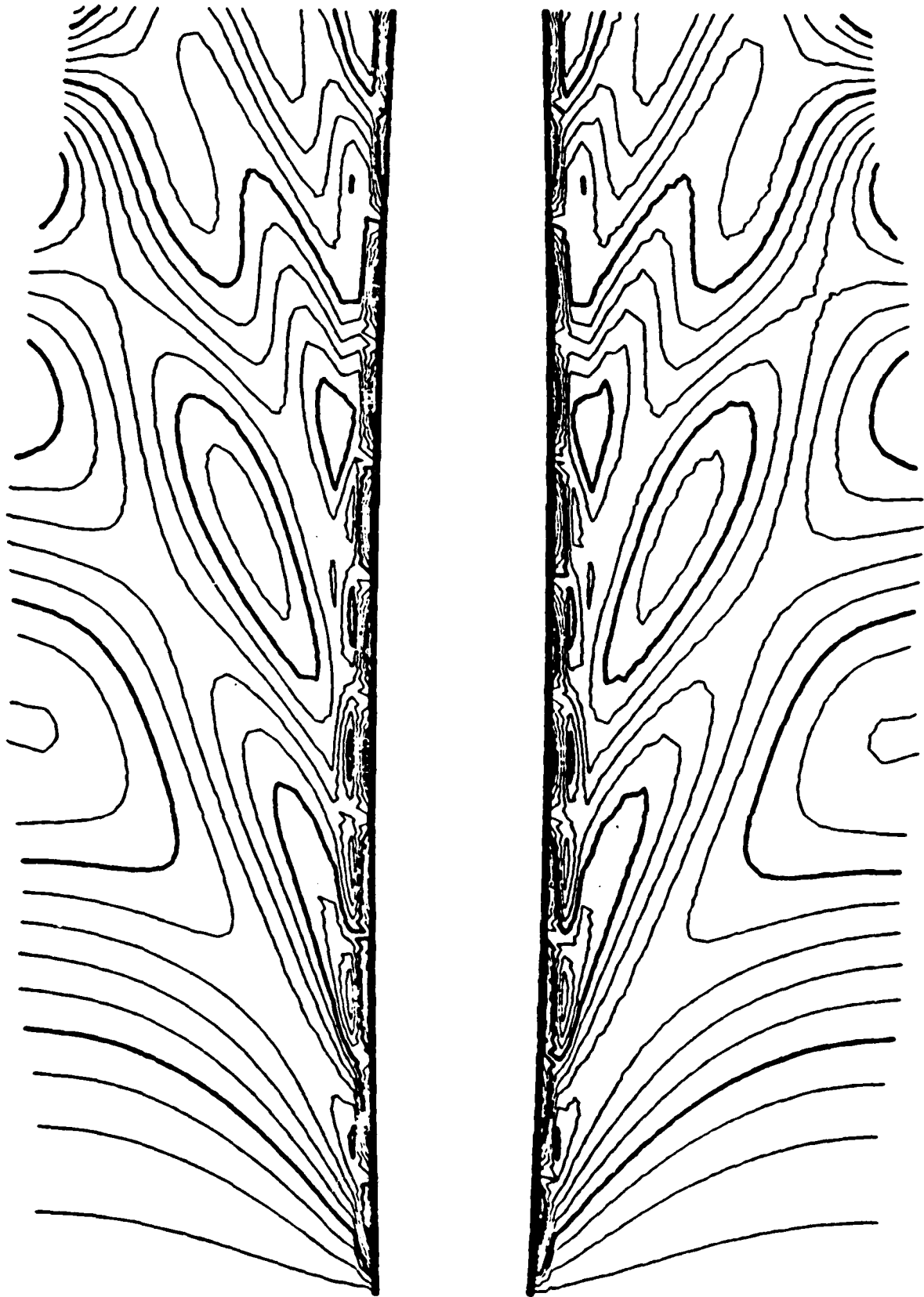
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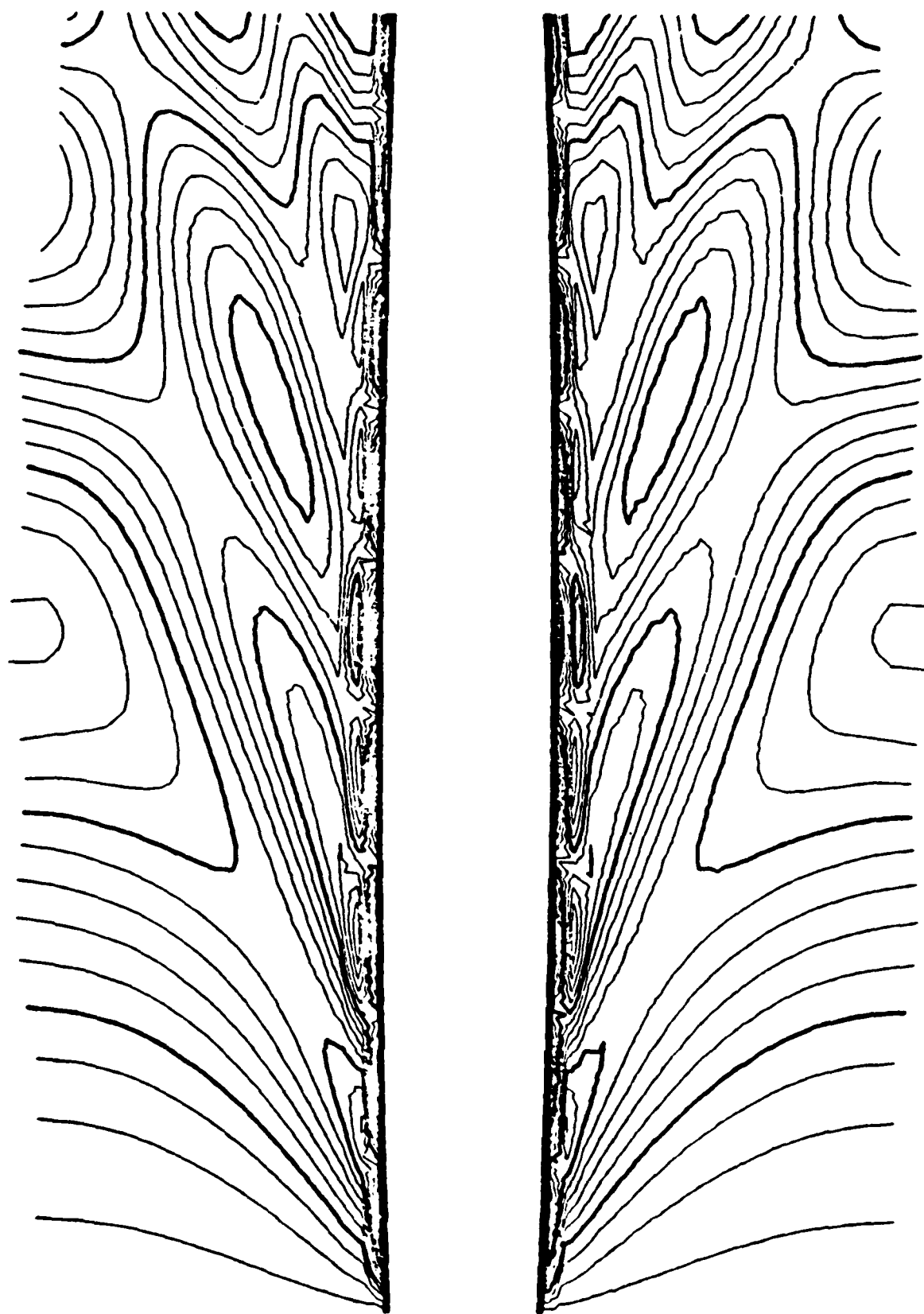
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