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A WALL INTERFERENCE ASSESSMENT/CORRECTION SYSTEM

FINAL REPORT
JUNE, 1991 - JUNE, 1994

Dr. C.F. Lo, Principal Investigator
University of Tennessee Space Institute

NASA Ames Research Center NAG 2-733

Ames Research Center
Moffett Field, CA 94035-1000

INSTITUTION:

CSTAR - Center for Space
Transportation and Applied Research
UTSI Research Park
Tullahoma, TN 37388-8897

Phone 615-455-9294 or 5884

Title: A Wall Interference Assessment/Correction System

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Principal Investigator:
Dr. C. F. Lo, UTSI

Other Investigators
Mr. W. L. Sickles, Research Engineer, CSTAR
Dr. N. Ulbrich, GRA and Research Engineer, UTSI
Mr. Glenn Overbey, GRA/UTSI
Ms. Cathy X. Qian, GRA/UTSI

Technical Officer:
Dr. Frank W. Steinle, NASA/Ames Research Center

This document lists the results obtained by the grant during the period of June, 1991 to June, 1994. The technical results of the last period are included in detail in the present report. The technical accomplishments were presented in the individual semi-annual reports as the results were obtained during that period. Also, the major results were presented in technical conferences and/or documented as technical papers.

Technical Objectives

A Wall Signature method originally developed by Hackett has been selected to be adapted for the Ames 12-ft Wind Tunnel WIAC system in the project. This method uses limited measurements of the static pressure at the wall, in conjunction with the solid wall boundary condition, to determine the strength and distribution of singularities representing the test article. The singularities are used in turn for estimating wall interference at the model location. The development and implementation of a working prototype will be completed, delivered and documented with a software manual.

The WIAC code will be validated by conducting numerically simulated experiments rather than actual wind tunnel experiments. The simulations will be used to generate both free-air and confined wind-tunnel flow fields for each of the test articles over a range of test configurations. Specifically, the pressure signature at the test section wall will be computed for the tunnel case to provide the simulated "measured" data. These data will serve as the input for the WIAC method--Wall Signature method. The performance of the WIAC method then may be evaluated by comparing the corrected parameters with those for the free-air simulation.

The following two additional tasks are included in the Supplement No. 1 to the Basic Grant. (1) On-line wall interference calculation: The developed wall signature method (modified Hackett's method) for Ames 12-ft Tunnel will be the pre-computed coefficients which facilitate the on-line calculation of wall interference, and (2) Support system effects estimation: The effects on the wall pressure measurements due to the presence of the model support systems will be evaluated.

Status of Progress

This is the final report. The grant was extended by NASA Ames to June 30, 1994 subject to no increase in authorized funding on October 13, 1993.

The tunnel wall boundary layer effects on the wall interference have been investigated in the last period (January-June, 1994) and is reported here in detail. A summary of the accomplishment for the grant will be given in the last section.

The viscous boundary layer effects on all the current wall interference calculation was neglected since the viscous effects are only restricted in the narrow region near the tunnel wall. However, the growth of boundary layer on the solid tunnel wall may affect the potential flow assumption and thus the results of the wall interference calculation. The effort of the last period is to investigate the wall boundary layer effects on the tunnel wall interferences.

Technical Discussion

A boundary layer analysis code developed at NASA by Harris (Ref. 1) is selected to calculate boundary layer thickness and displacement thickness. This code uses finite difference method for both planar and axisymmetric flows including laminar and turbulent boundary layers. To impose the boundary layer condition to the tunnel solid wall, an equivalent boundary condition is applied rather than to add the displacement thickness directly to tunnel wall as the conventional way to take account of boundary layer effects. This equivalent boundary conditions are not only more accurate but also specially suitable for incorporating to a panel method such as PMARC code.

The equivalent boundary condition for the inviscid analysis in the displacement thickness is derived from the continuity equation (see page 200 in Ref. 2). With this condition, the computation can be performed using inviscid panel method--PMARC code. The **first** step is to calculate the inviscid flow with the zero normal velocity (i.e., tangential flow condition) at the tunnel wall surface. The **second** step is to calculate the displacement thickness using the boundary layer equation with the pressure distribution obtained from the first step. Then, the inviscid calculation is ready to be performed by combining the inviscid tangential velocity distribution and the displacement thickness into the equivalent boundary condition as the **third** step. These calculation includes the viscous boundary layer effects on the tunnel wall interferences.

The specific example given below is a biconvex body of revolution in a circular wind tunnel. The pressure profile along the tunnel wall is resulted from inviscid calculation of PMARC code as shown in Figure 1. Based on this pressure distribution, the displacement thickness computed by Harris' boundary layer code is shown in Figure 2. The equivalent boundary condition is shown in Figure 3, obtained from data in Figures 1 and 2, provides the boundary condition for the inputs of the third step calculation using the PMARC to determine the tunnel interference. Figure 4 gives the wall interference results of the comparison between inviscid and viscous calculation at several location in the tunnel. For this specific case, it all appears that the differences of inviscid and viscous results are negligibly small. Thus, the conclusion may be drawn that the inviscid wall interference theory seems accurate enough to estimate the interference correction under the present small disturbance flow conditions. It is justified to use inviscid theory for the current tunnel data correction within the small perturbation assumption.

Summary:

Five Semi-Annual Reports have been submitted to NASA reporting the results of the grant. The highlights of the accomplishments are summarized as follows:

A. Theoretical Development of the Wall Signature Method was reported in Semi-Annual Report #2, Jan-June, 1992 and was published in an AIAA conference paper--AIAA 92-3925 entitled "Blockage Correction in Three-Dimensional Wind Tunnel Testing Based on the Wall Signature Method," July, 1992

B. The Wall signature method were verified in a rectangular wind tunnel test section and implemented for the NASA/ARC 12-ft tunnel which were reported as a Ph.D. dissertation, University of Tennessee, Knoxville, TN, August, 1992 by Norbert Ulbrich, GRA/UTSI.

C. The effects of the model support system in the 12-ft Pressure Tunnel are reported in Semi-Annual Report #4, Jan-June, 1993 and was published as a Master Thesis, University of Tennessee, Knoxville, TN, May, 1993 by Glenn Overbey, GRA/UTSI.

D. The software implementation of the application of the Wall Signature Method to NASA/ARC 12 Pressure Wind Tunnel was reported in Semi-Annual Report #5, July-Dec, 1993. The Software Manual of the software was also included in the same Semi-Annual Report.

E. The boundary layer effects on the wall interference calculation is reported in the Final Report. These results will be reported as a Ph. D. dissertation, University of Tennessee, Knoxville, TN by Cathy X. Qian, GRA/UTSI in the coming months.

F. Two papers will be published based on the results of the current grant: (1) "Wind Tunnel Interference Calculated by a Panel Method," AIAA 95-0794 and (2) "Two-Variable Method for Blockage Wall Interference in a Circular Tunnel," Journal of Aircraft, Sept.-Oct. 1994.

References:

1. Harris, J.E., Blanchard, D.K.; "Computer Program for Solving Laminar, Transitional, or Turbulent Boundary Layer Equations for Two-Dimensional and Axisymmetric Flow," NASA TM 83207, February 1982.

2. Moran, J.; "An Introduction to Theoretical and Computational Aerodynamics," John Wiley, 1984, p. 200.

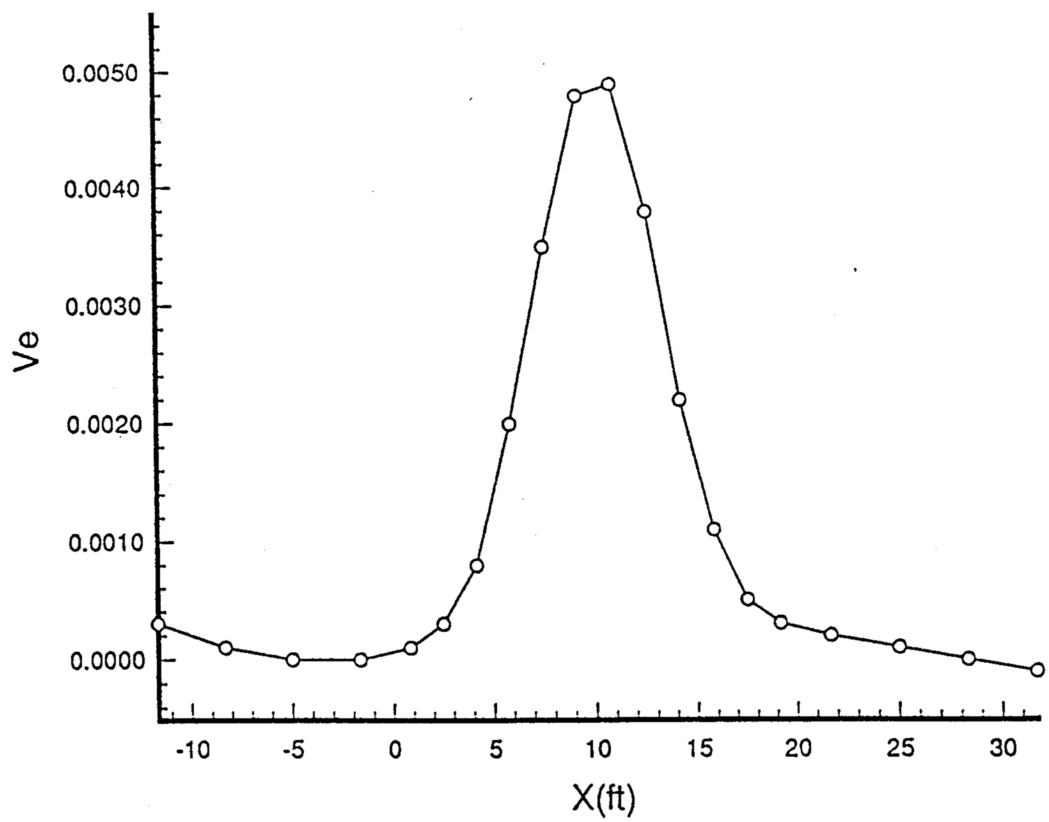

Figure 1. Non-dimensional surface tangential velocity distribution obtained from the PMARC code.

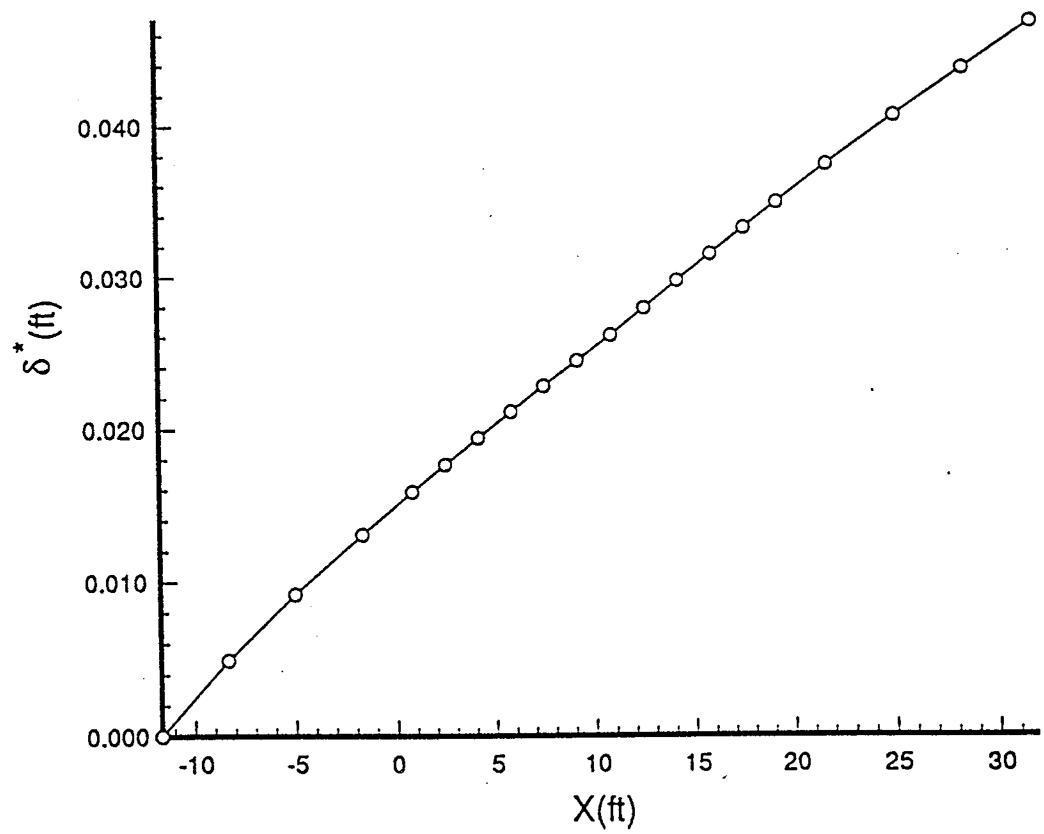

Figure 2. The distribution of the boundary-layer displacement thickness obtained from BL code.

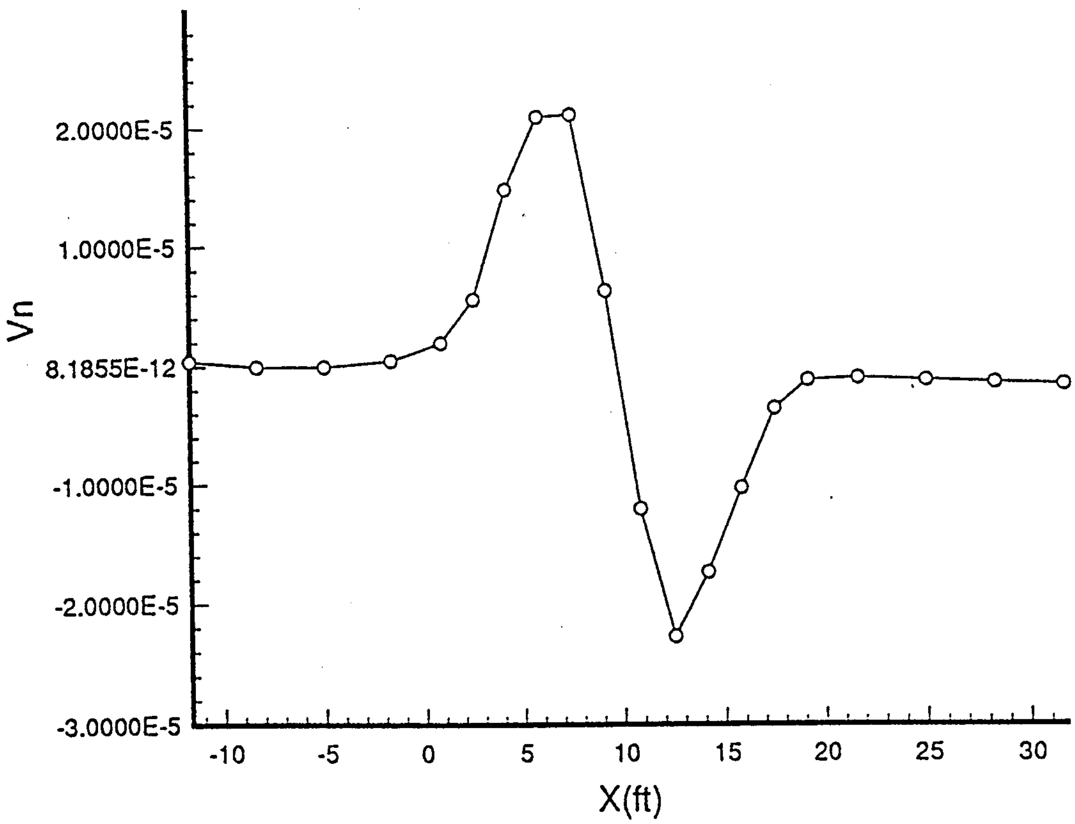

Figure 3. Equivalent normal velocity distribution along the stream direction.

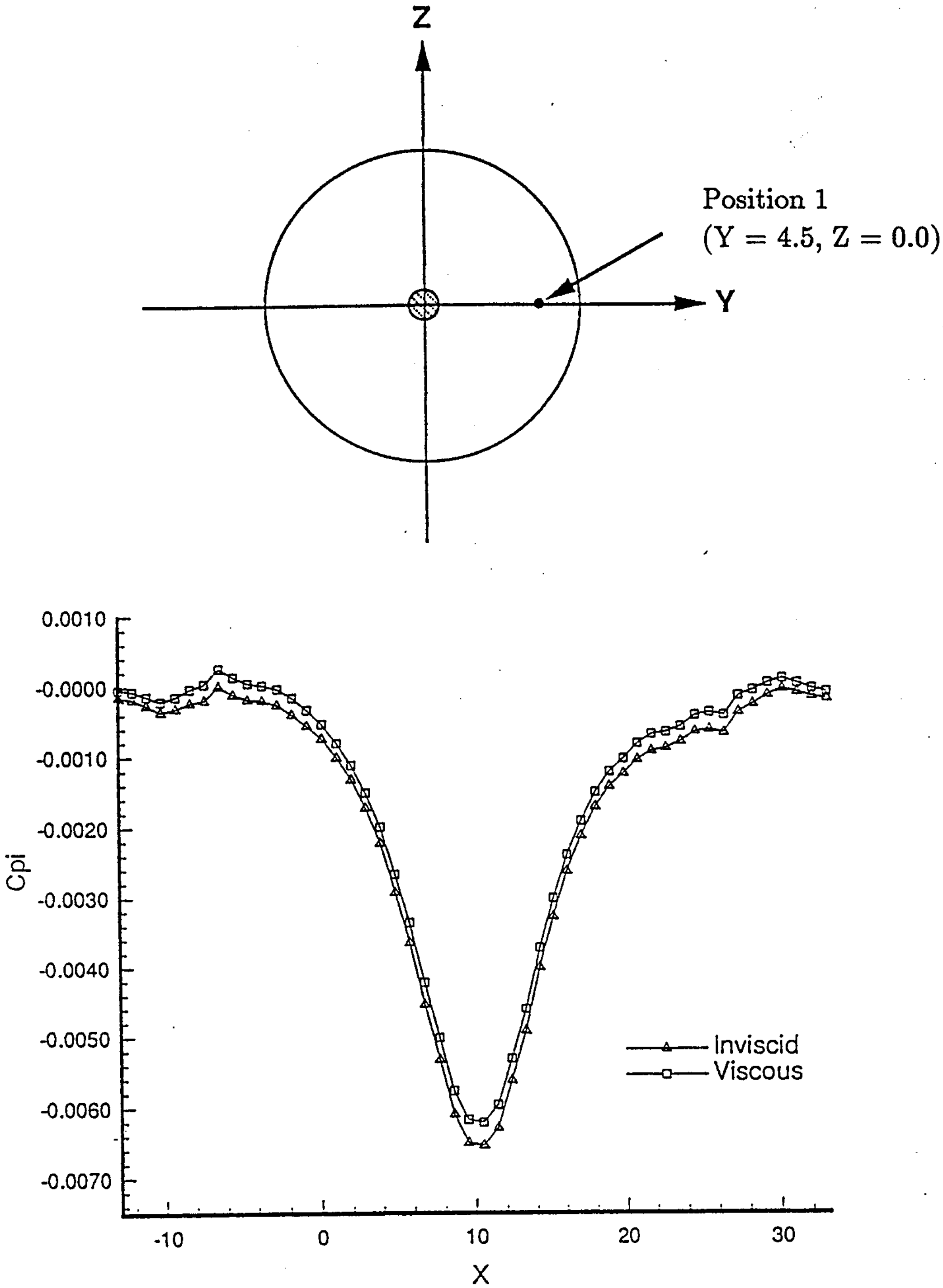

Figure 4a. Comparison of wall interference pressure coefficient distribution between inviscid and viscous results at position 1.

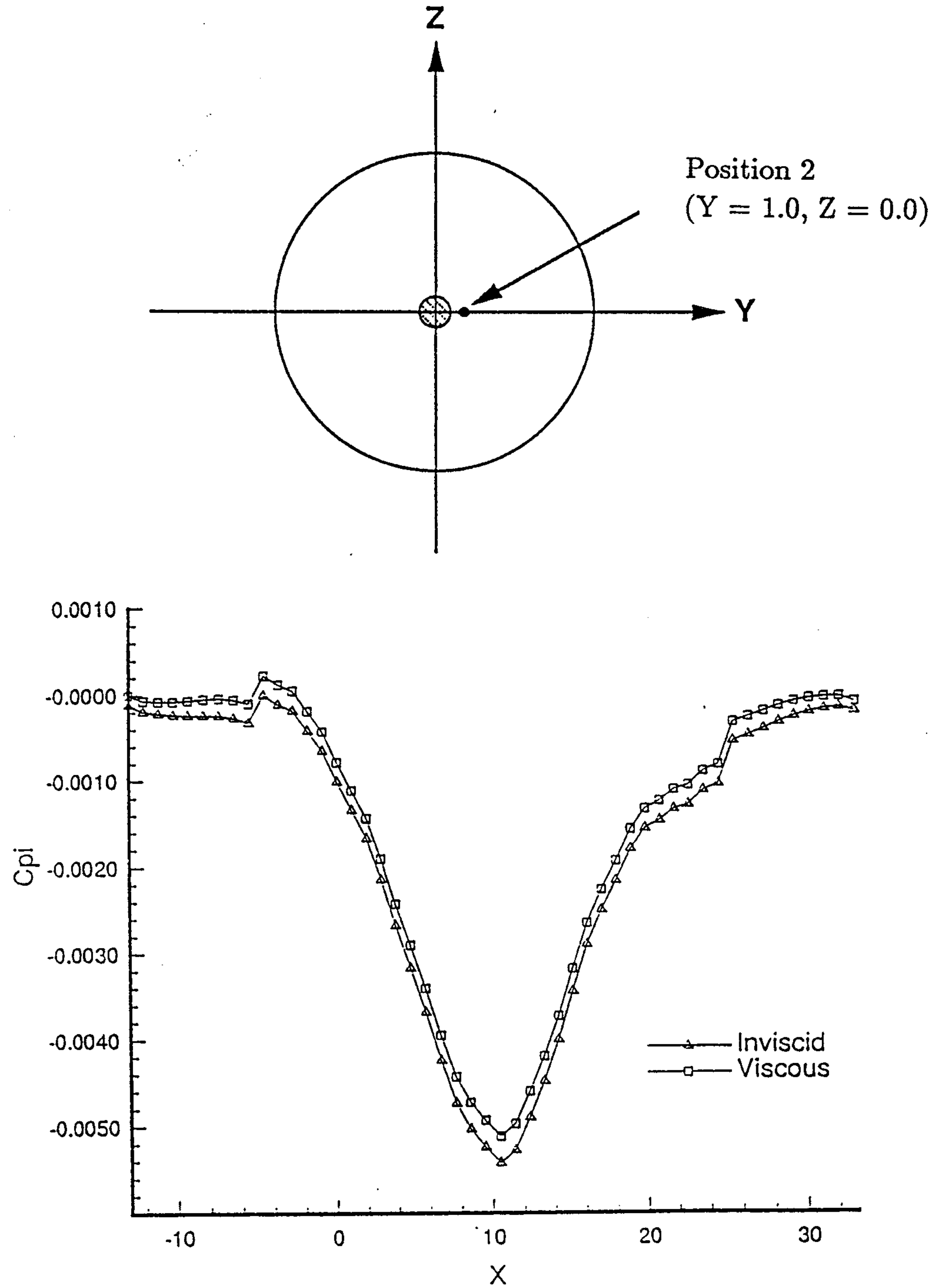

Figure 4b. Comparison of wall interference pressure coefficient distribution between inviscid and viscous results at position 2.