Eleventh International Conference on Domain Decomposition Methods

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Edited by CHOI-HONG LAI, PETTER E. BJØRSTAD, MARK CROSS AND OLOF WIDLUND

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Preface

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Instruction for the Preparation of Final Scripts

A.Uthor1[1], A.Uthor2[2]

Introduction

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2

A Domain Decomposition Technique for Viscous/Inviscid Coupling

C.-H. LAI[1], A.M. CUFFE[2], & K.A. PERICLEOUS[3]

INTRODUCTION

The numerical simulation of viscous flows past realistic configurations using time-dependent compressible Navier-Stokes for high Reynolds numbers requires a large amount of computing time [cfd94]. Although steady-state solutions of a compressible inviscid flow past over a complete aircraft described by the Euler equation can be obtained in just a few minutes time, modelling 3-D unsteady flows to understand the aerodynamics of a complete aircraft is still a grand challenge. With the limits of computing resources, it is important to develop efficient numerical technqiues which are suitable for implementation on parallel computers and for engineering design purposes.

One such technique relies upon a problem partitioning concept. The concept in relation to viscous flows past over obstacles was originally observed by Prandtl [Pra04], of which the following two observations are involved. When a viscous fluid flow past a solid boundary, tangential and normal components of the velocity must both equal to the components of the velocity of the surface, and fluid sticks to the surface. For an ideal inviscid fluid, only the normal components are equal and there is no restriction on tangential slip of fluid relative to the boundary. The fundamental differences lead

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to the idea of a boundary layer first proposed by Prandtl. It is a thin layer of fluid adjacent to the solid surface within which viscous effects are dominant and that such effects become negligible outside the thin layer. Hence it is valid to divide the flow region into two parts, i.e. the boundary layer and the inviscid flow outside the layer.

TRUNCATION TECHNIQUES

Truncation methods have been around for a long time. It has been used, in a different form, for the determination of local hyperbolic and elliptic regions in a plane transonic flows for shock location [MC71] or local adaptive mesh refinement for shock capturing. This Section describes two frequently used truncation techniques related to flows past an obstacle.

Prandtl's truncation

Prandtl introduced the idea of boundary layer by neglecting the effect of viscosity outside the thin layer next to a surface. One assumption to implement the idea in 2-D incompressible viscous flows past an obstacle described by

$$\nabla \cdot \underline{u} = 0 \tag{2.1}$$

$$\frac{\partial \phi}{\partial t} + \nabla \cdot (\underline{u}\phi - \nu \nabla \phi) = -\frac{1}{\rho}\frac{\partial p}{\partial \underline{n}} \tag{2.2}$$

where $\phi = u, v$ and $\underline{u} = (u, v)^T$ is $u \gg v$. The assumption leads to the boundary layer equations as described by

$$\nabla \cdot \underline{u} = 0 \tag{2.3}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} \tag{2.4}$$

$$\frac{1}{\rho}\frac{\partial p}{\partial y} \approx 0 \tag{2.5}$$

There are other assumptions which reduces the 2-D incompressible viscous flow model to other turbulent boundary layer models [Kno86] or models suitable for regions with separations and wakes [GWB73] [Rau75].

The upstream Reynolds number is chosen to be 1000. Figure 2.1 shows the velocity profiles against the distance along η-axis, obtained at $\xi = 0.46$ and $\xi = 0.66$. Figure 2.1 shows the effect of $||u_{\epsilon,\sigma} - u_{fv}||_\infty$ for the aerfoil problem.

CONCLUSIONS

The scalar truncation method is extended to a vector truncation method and is embedded in a cell-centred finite volume method. The effect of the threshold parameter σ is insignificant to the accuracy of the solution. The choice of the threshold parameters namely, σ and ϵ, is effectively equivalent to the determination of a minimal inner region defined by the thickness function t. The present approach shows that the computation of velocity gradients in the finite volume method can be used in both the evaluation of the line integrals as well as for viscous effect comparison.

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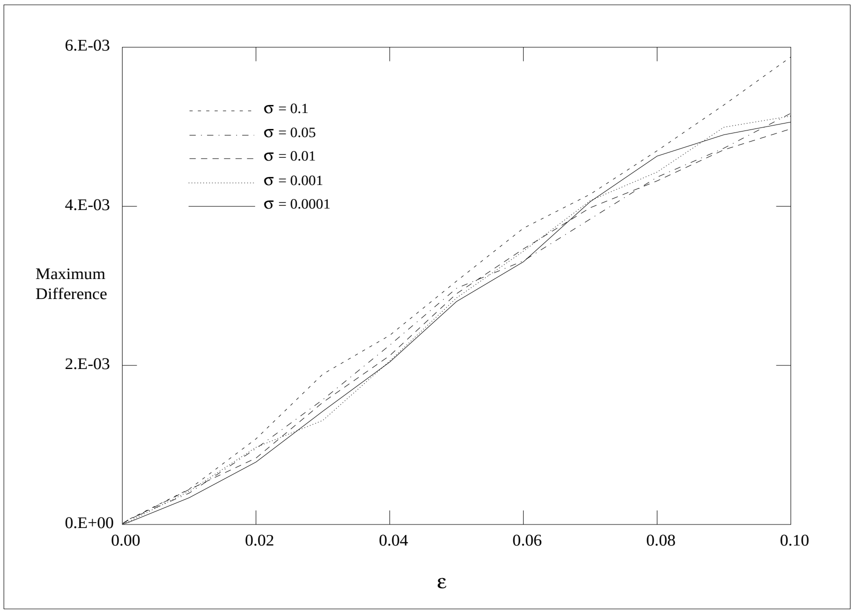

Figure 2.1 $||u_{\epsilon,\sigma} - u_{fv}||_\infty$ for some values of ϵ and σ.