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3D Metric-based anisotropic mesh adaptation for vortex capture

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Abstract

A mesh adaptation procedure is presented to capture a tip vortex in a CFD calculation. The objective is to reduce the numerical diffusion by refining the mesh in the vortex core and coarsen it away from its center. The error estimator of the adaptation scheme is based on the Hessian of a scalar field. The sum of the original vorticity and a transported vorticity is used to calculate the Hessian. The transported vorticity is calculated as a separate equation, which has no influence on the flow computation. To assess the quality of the process, a laminar test case is studied.

Keywords: Mesh adaptation; Metric; Vortex capture; Anisotropy; Transport equation; Vorticity

1. Introduction

Vortices in CFD calculations are difficult to capture accurately. In particular, the tip vortex generated by a wing tip has a long and slow expansion while CFD simulations for this flow often show a rapidly increasing vortex radius. Many authors have tried to capture vortices using CFD but with limited success [10,14]. One consequence of this numerical phenomenon is, for example, an inaccurate prediction of the damage done by cavitation.

Previous studies have identified two main reasons for the rapid diffusion of the vortices. The first one is related to the spatial discretization imposed by the numerical schemes and the second one is associated with the turbulence model used by the CFD code. This paper intends to reduce the numerical diffusion introduced by the spatial discretization by means of mesh adaptation. A quantification of mesh quality has been done by [28] by calculating a numerical viscosity for different meshes. Their results show that the numerical viscosity induced by the spatial discretization may vary by more than two orders of magnitude.

When the position of vortices is known in advance, the mesh can be built accordingly. However, when the position of vortices is not known, an automatic mesh adaptation method should prove useful to adequately refine and orient mesh elements. The mesh adaptation procedure should account for the anisotropy of the vortex by deforming elements along preferred directions. Also, the adaptation must coarsen the mesh in areas of low vorticity, even coarser than the original mesh, if needed. An appropriate error estimator providing adequate information to allow mesh adaptation is therefore required.

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