

by Zenotech

Verification & Validation Document

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Preface

This document contains verification and validation evidence for the Computational Fluid Dynamics solver zCFD. This is primarily a reference for users and developers of the software.

The cases in this document were run in 2013 with the zCFD of that time. Current verification and validation results are produced by the zCFD test suites.

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Chapter 1

zCFD

1.1 Introduction

This Verification guide contains selected cases to which the zCFD many-core accelerated Computational Fluid Dynamics solver has been applied. For each of these cases a comparison has been made to various compiled validation results, thus enabling the user to easily discern the accuracy achieved by the solver.

Chapter 2

Zero Pressure Gradient Flat Plate

This case exercises the turbulence model through comparing the turbulent boundary layer profile directly with theory given the absence of a pressure gradient. This test is applied to a series of meshes with increasing y^+ in order to stress the automatic wall function implementation

2.1 Conditions

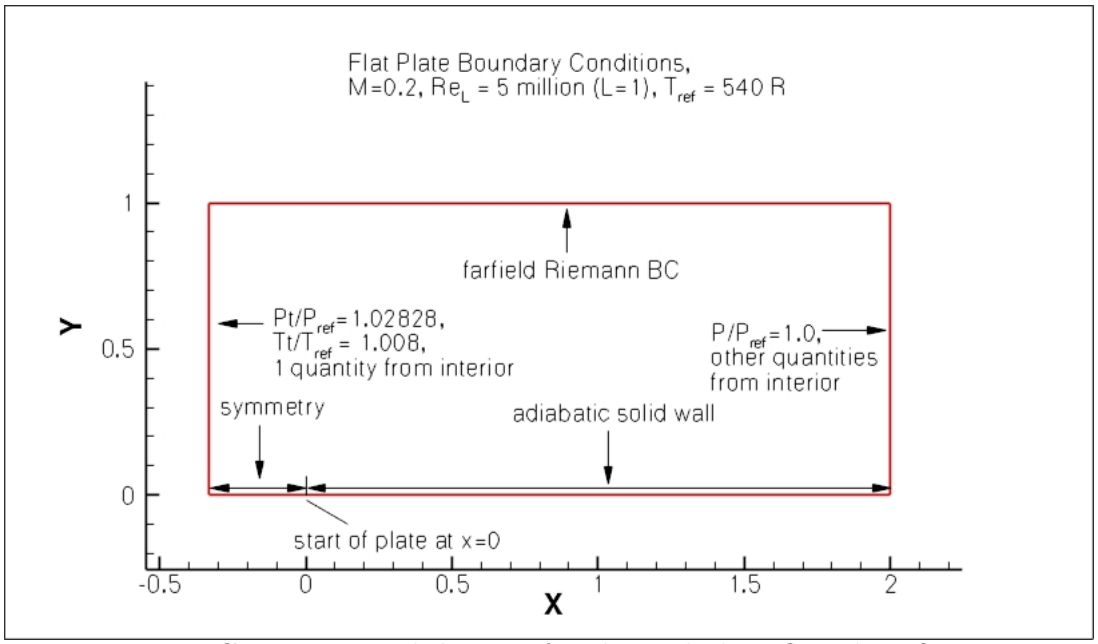


Figure 2.1: Computational domain for the turbulent flat plate flow case.

2.2 Mesh

68 x 48 cells (56 cells on plate)

2.3 Results

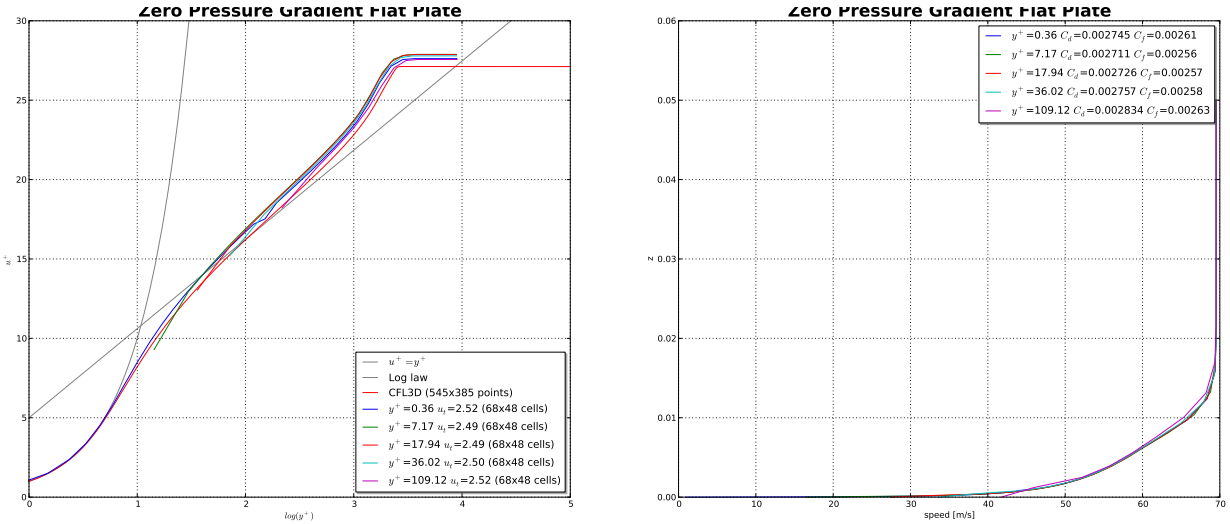


Figure 2.2: Boundary layer profiles at $x = 0.97$

Mesh sensitivity

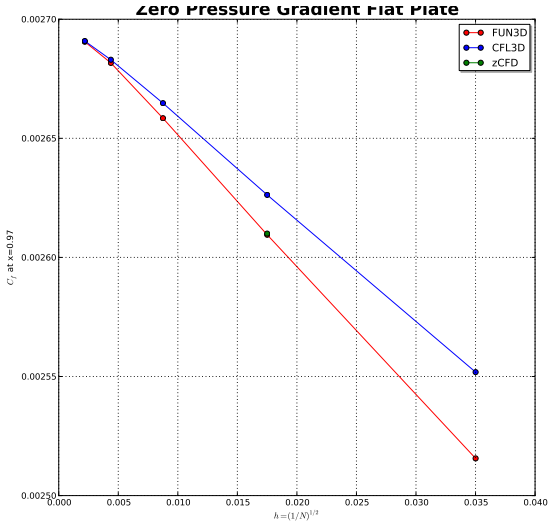


Figure 2.3: Mesh convergence comparison for C_f

2.4 References

1. `http://turbmodels.larc.nasa.gov/flatplate.html`
2. `http://turbmodels.larc.nasa.gov/flatplate_val.html`

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Chapter 3

NACA0012

For this section the computational mesh is positioned over a boundary corresponding to Figure 4.1.

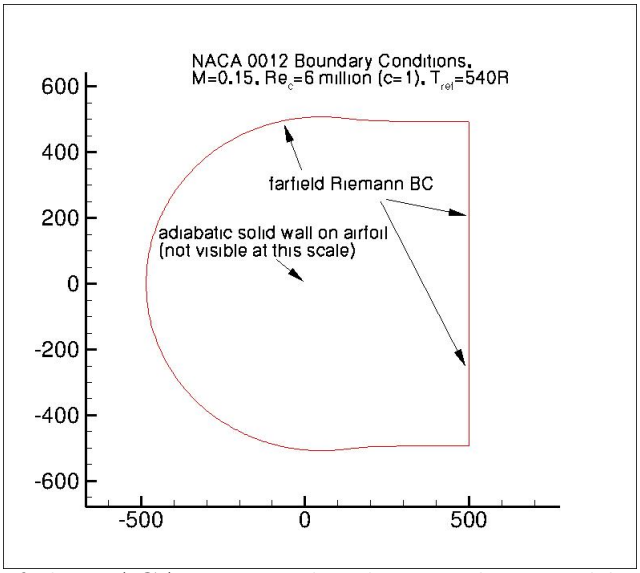


Figure 3.1: layout of the NACA 0012 grids, along with typical boundary conditions.

The angle of flow is then altered for each of the subsequent cases from 0 degrees to 10 degrees and finally 15 degrees, thus leading to a significant variation in results.

3.1 Conditions

3.2 Mesh

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3.3 Results

The results are compared to experiment and to CFL3D at three angles of attack 3.2.

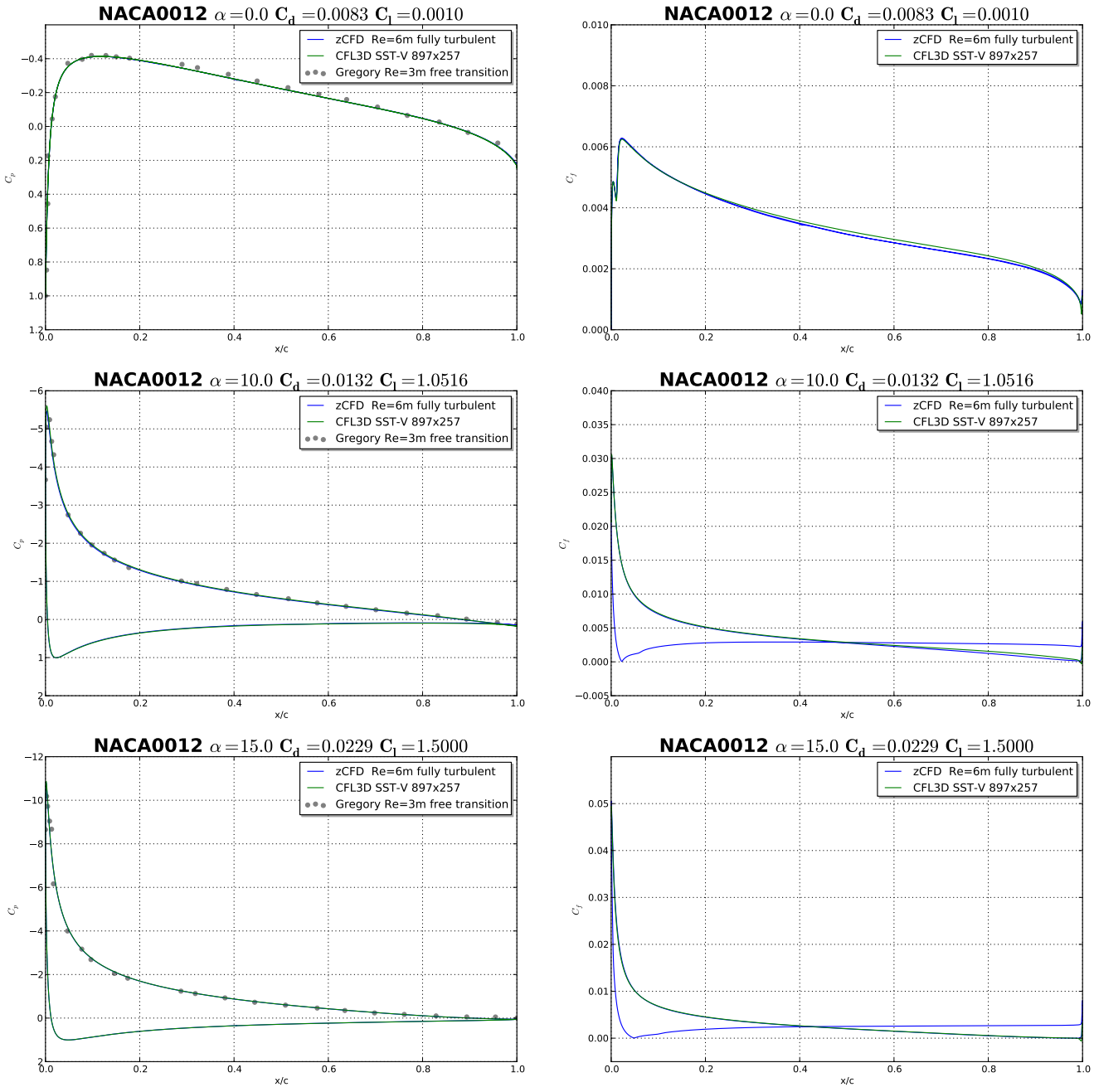


Figure 3.2: C_p and C_f comparisons at the three test angles

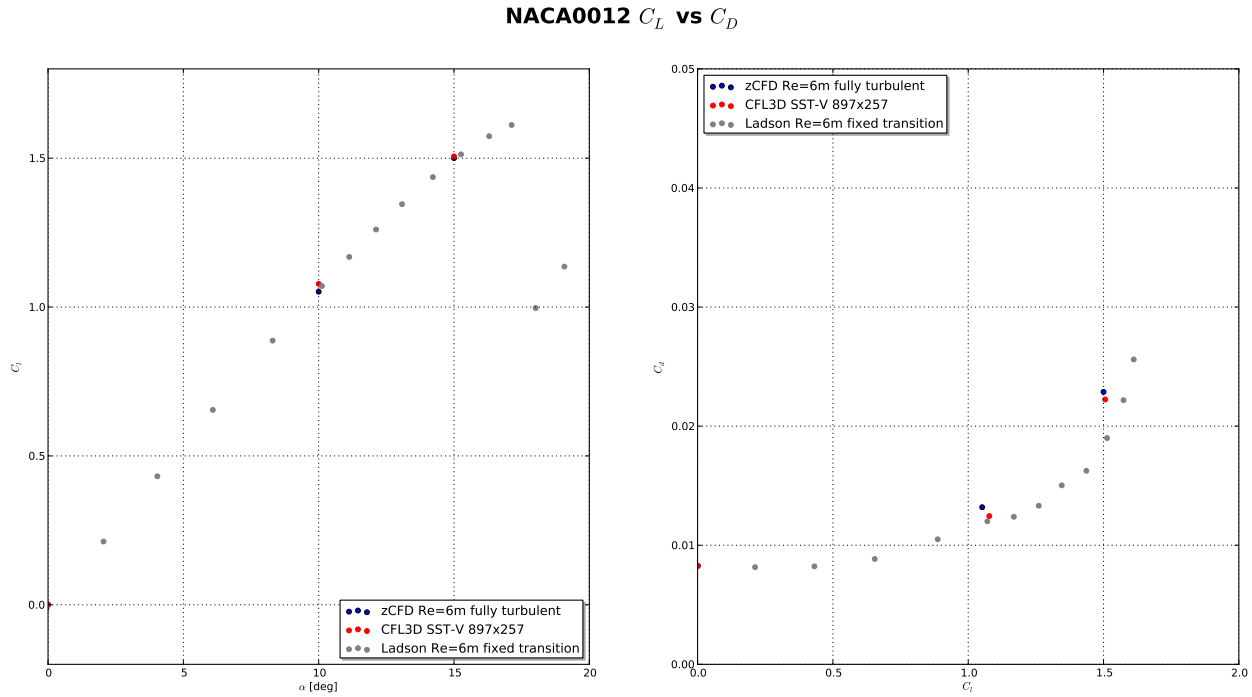


Figure 3.3: C_l vs α comparison with Ladson's experimental data.

3.4 References

1. http://turbmodels.larc.nasa.gov/naca0012_val.html

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Chapter 4

Cylinder

This verification case is concerned with the laminar flow over a cylinder. This corresponds to a flow which is essentially two dimensional and has periodic vortex shedding, as demonstrated by Figure 4.3.

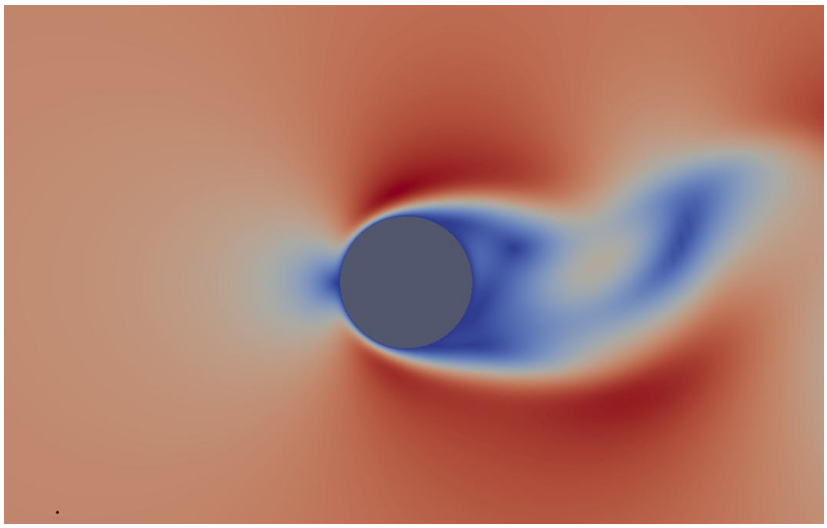


Figure 4.1: 2D cross-section of the pressure distribution of flow over the cylinder.

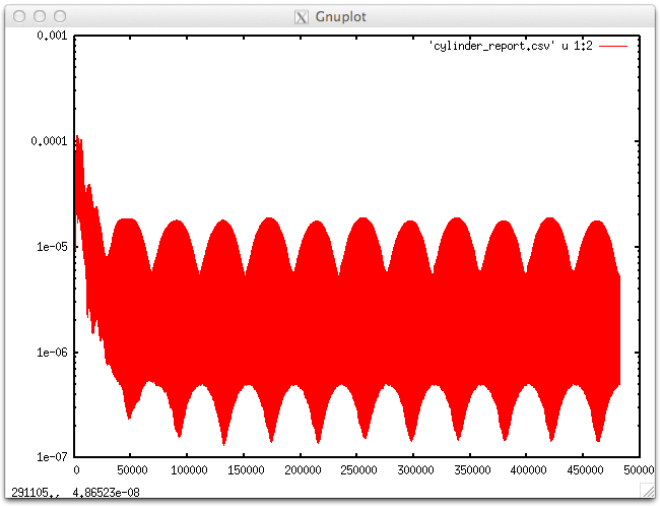


Figure 4.2: A Residual plot over the number of computed cycles for the verification case.

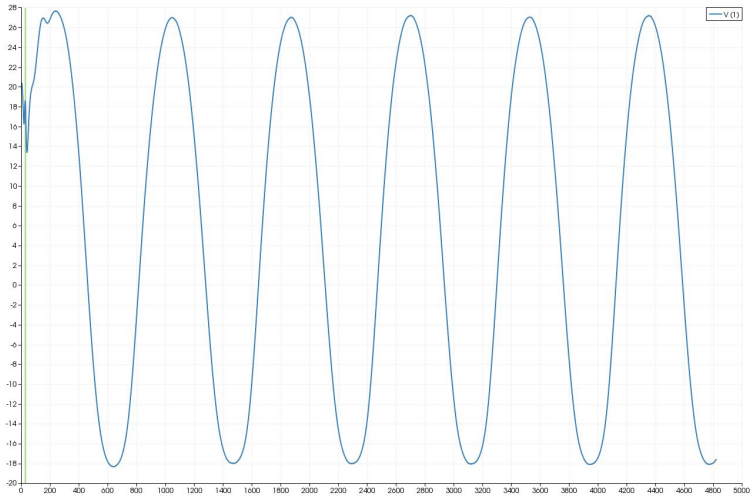


Figure 4.3: Time stability of a selected downstream location.

Strouhal number

The dimensionless frequency S_t is given by

$$S_t = \frac{fD}{U} \tag{4.1}$$

where D is the cylinder diameter equal to $1.0m$ and U is the freestream velocity equal to $66.8163m/s$.. The parameter f is the frequency of the vortex shedding. To measure this quantity, the velocity and pressure at a point downstream of the cylinder and away from the center of the wake as given by Figure 4.3 are used.
It's important to use a point away from the center of the wake otherwise the influence of the vortices from both sides will be included and therefore give a value of the frequency double the individual vortex shedding frequency.
The experimental value of the Strouhal number ranges from $0.179 - 0.182$.
Achieving a value in this range verifies the dual time stepcalculation, and for this verification case, the value of S_t is calculated thus

$$Distance\ between\ peak \approx 827 \tag{4.2}$$

$$Frequency = 1.0/(827 * 0.0001) = 12Hz \tag{4.3}$$

$$S_t = \frac{fD}{U} = 12 * 1/66.813 = 0.18 \tag{4.4}$$

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Chapter 5

Drag Prediction Workshop - CRM

Chapter 6

Ahmed Body