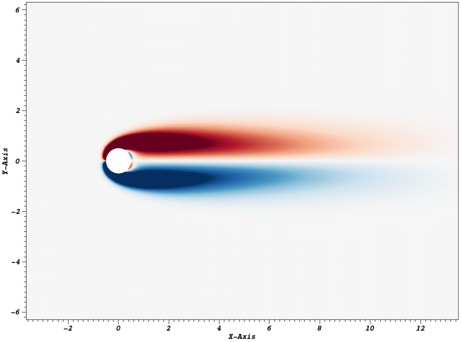
Numerical Simulation of Compressible Flows with Immersed Boundaries Using Discontinuous Galerkin Methods

Bachelor thesis by Simone Stange
Prof. Dr.-Ing. habil. Martin Oberlack
Betreuer: Dr.-Ing Björn Müller



Outline

Introduction

kurzes blabla

Flow Properties

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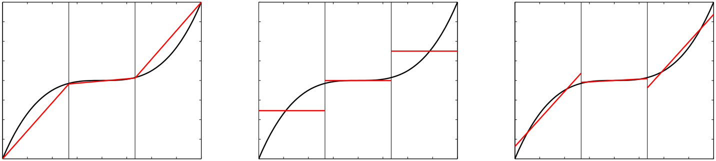
compressible flow
ideal gas mit gamma Ma = def , 0.2 Re, Pr

Compressible Navier-Stokes Equation

2d
conserved flow variables density, momentum, energy
dimensionless variables
gleichung, aufgeteilt in temporal derivative, convective fluxes, viscous fluxes

The Discontinuous Galerkin Space Discretisation



(a) First order FEM (b) Zeroth order DG (FVM) (c) First order DG

Abbildung: Comparison of FEM, FVM and DG

DG space discretisation Vorgehen, Bildchen, fluxes

The Runge-Kutta Time Discretisation

RK time discretisation Endformel, Tabelle, cfl criterion

The Immersed Boundary Method

regions mit Bild, Aufteilung Integrale mass matrix rk time discretisation formel cell agglomeration

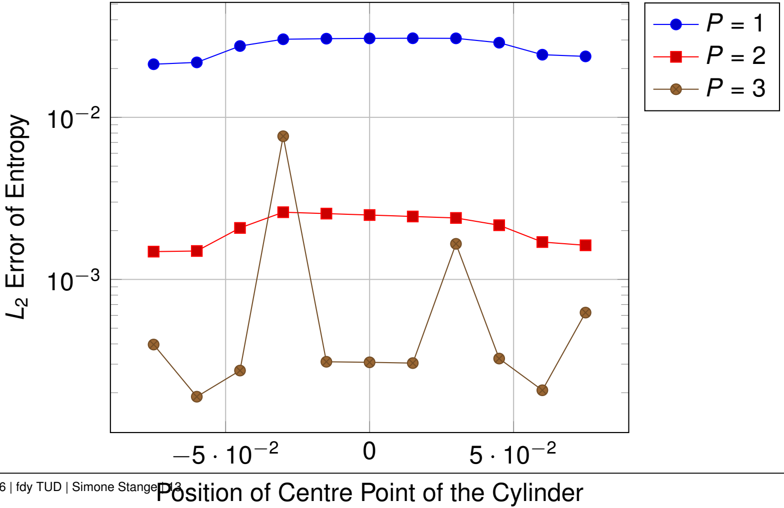
Problem Specification

Gitter, Bild, domain, level set, isentropic inviscid flow mit gleichung -> s=0

Robustness Study – Preparation

shift, degree 1 bis 3, agglo 0.5, 64 mal 64 cells Parameter, was wird getan

Robustness Study – Evaluation



Comvergence Study – Preparation

Parameter, was wird getan

Convergence Study – Evaluation

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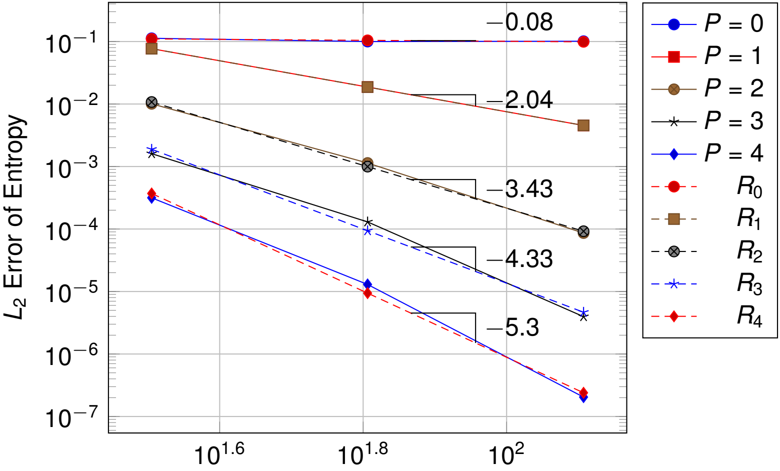
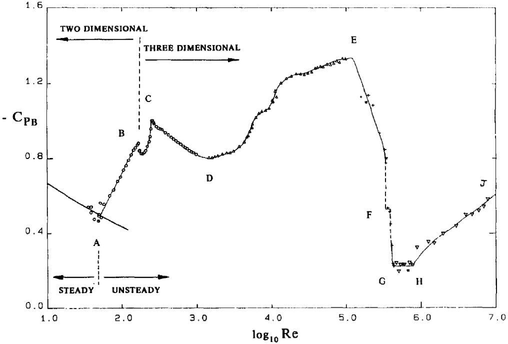


fdy

Theory – Differentiation into Flow Regimes

- $40 - 50 < \mathrm{Re} < 190$: laminar vortex shedding,
- $190 < \mathrm{Re} < 260$: 3d wake-transition regime,



Theory – Laminar Steady Regime

laminar steady regime Bild

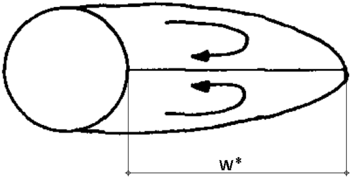


Abbildung: Wake Separation Length, Taken from [**?**], Modified

Theory – Laminar Vortex Shedding

Bild

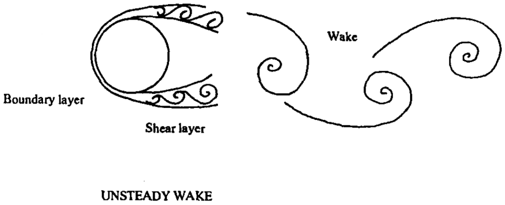


Abbildung: Kármán Vortex Street [?]

Karman vortex street frequency /strouhal

Simulation Properties

simulation parameter gitter cD, CL, W*, St

Simulation at Re = 20 I

Re = 20	Source	2d/3d	W^*	C_D
Numerical – Incompressible	dennis1970numerical	2d	0.94	2.05
	fornberg1980numerical	2d	0.91	2.00
	linnick2005high	2d	0.93	2.06
Experimental	coutanceau1977experimental	-	0.93	-
	tritton1959experiments	-	-	2.09
Numerical – Compressible	brehm2015locally (Ma = 0.1)	3d	0.96	2.02
	ayers	2d	0.975	2.06
	Present Results:	2d	0.928	2.136

Tabelle: Comparison of Results for W^* and C_D, taken from [**?**], modified

Simulation at Re = 40

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Re = 40	Source	2d/3d	W^*	C_D
Numerical – Incompressible	dennis1970numerical	2d	2.35	1.52
	fornberg1980numerical	2d	2.24	1.50
	linnick2005high	2d	2.28	1.54
Experimental	coutanceau1977experimental	-	2.13	-
	tritton1959experiments	-	-	1.59
Numerical – Compressible	brehm2015locally (Ma = 0.1)	3d	2.26	1.51
	ayers	2d	2.250	1.605
	Present Results:	2d	2.201	1.608

Tabelle: Comparison of Results for W^* and C_D, taken from [**?**], modified

re 40 tabelle, plot, drag over time, vorticity

Simulation at Re = 100

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Re = 100	Source	2d/3d	*St*	C_D
Numerical – Incompressible	gresho1984modified	2d	0.18	1.76
	linnick2005high (λ = 0.056)	2d	0.169	$1.38 \pm$
	linnick2005high (λ = 0.023)	2d	0.1696	$1.34 \pm$
	FLM:14223	2d	0.165	1.25
	saiki1996numerical	2d	0.171	1.26
	FLM:14223	3d	0.164	1.24
	liu1998preconditioned	3d	0.165	$1.35 \pm$
Experimental	berger1972periodic	-	$0.16 - 0.17$	-
	clift2005bubbles	-	-	1.24
	williamson1996vortex	-	0.164	-

Simulation at Re = 200

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Re = 200	Source	2d/3d	*St*	C_D
Numerical – Incompressible	belov1995new	2d	0.193	1.19 ± 0.0
	gresho1984modified	2d	0.21	1.76
	linnick2005high (λ = 0.056)	2d	0.199	1.37 ± 0.0
	linnick2005high (λ = 0.023)	2d	0.197	1.34 ± 0.0
	miyake1992numerical	2d	0.196	1.34 ± 0.0
	FLM:14223	2d	0.198	1.321
	saiki1996numerical	2d	0.197	1.18
	FLM:14223	3d	0.181	1.306
	liu1998preconditioned	3d	0.192	1.31 ± 0.0
Experimental	berger1972periodic	-	$0.18 - 0.19$	-
	clift2005bubbles	-	-	1.16
	williamson1996vortex	-	0.181	-

Summary

conclusion

Outlook

future works

The End

ende, fragen

Bibliography

bibliography

alle tabellen und graphen die man brauchen könnte in anhang