Inv.-Nr. D20608

WIENER MITTEILUNGEN

WASSER • ABWASSER • GEWÄSSER

INSTITUT WAR — Bibliothek —
Wasserversorgung, Abwassertechnik
Abfalltechnik und Raumplanung
Technische Universität Darmstadt
Petersenstraße 13, 64287 Darmstadt
TEL. 0 61 51/16 36 59 + 16 27 48
FAX 0 61 51/16 37 58

10 WIE 193

Band 193

Michael Tritthart

Three-Dimensional Numerical Modelling of Turbulent River Flow using Polyhedral Finite Volumes

Dissertationsschrift

Herausgeber:
O.Univ.-Prof. Dipl.-Ing. Dr.techn. Dr.h.c. Dieter Gutknecht
Institut für Wasserbau und Ingenieurhydrologie
Technische Universität Wien

Wien, 2005

WAR TU Darmstadt
57509694

Table of Contents

1 Introduction 1

1.1 Thematic Introduction 1

1.2 Objectives and Outline 3

2 Review of 3D CFD Programs for Hydraulic Engineering 5

2.1 Introduction 5

2.2 Software Packages 7

2.2.1 CFX-5 7

2.2.2 Comet 8

2.2.3 Delft3D 9

2.2.4 FEATFLOW 10

2.2.5 FIDAP 11

2.2.6 Flo++ 12

2.2.7 FLOW-3D 13

2.2.8 FLUENT 14

2.2.9 NaSt3DGP 15

2.2.10 PHOENICS 16

2.2.11 SSIIM 17

2.2.12 STAR-CD 18

2.2.13 SWIFT 19

2.2.14 TELEMAC-3D 20

2.3 Summary 21

3 Polyhedral Computation Grids 23

3.1 Background and Fundamentals 23

3.1.1 Conventional Computation Grids . . . 23
3.1.2 Voronoi Decomposition . . . 25
3.1.3 Fortune's Algorithm . . . 28
3.2 Modular System . . . 32
3.2.1 Background . . . 32
3.2.2 Base Module . . . 33
3.2.3 Boundary Module . . . 34
3.2.4 Structure Line Module . . . 35
3.3 Data Structure . . . 36
3.4 Terrain Elevation . . . 39
3.4.1 Background . . . 39
3.4.2 Bivariate Interpolation Method . . . 40
3.4.3 Kriging . . . 41
3.5 Grid Refinement . . . 43
3.6 Estimation of Water Surface Elevations . . . 46
3.7 3D Grid Geometry . . . 49

4 Governing Equations and Discretisation 56
4.1 Momentum Equations . . . 56
4.1.1 Equations . . . 56
4.1.2 Diffusive Term . . . 58
4.1.3 Convective Term . . . 61
4.1.4 Pressure Term . . . 64
4.1.5 Source Terms . . . 65
4.1.6 Complete Discretised Equation . . . 66
4.1.7 Basic rules of the Finite Volume Method . . . 66
4.2 Pressure Correction Equation . . . 67
4.3 Turbulence Modelling . . . 73
4.3.1 Turbulence Models . . . 73
4.3.2 Discretisation . . . 78
4.4 Boundary Conditions . . . 82
4.4.1 Inlet . . . 82
4.4.2 Outlet . . . 85
4.4.3 Solid Walls . . . 85
4.4.4 Free Surface . . . 88

4.5 Solution of Equations . . . 88
4.5.1 Solver . . . 88
4.5.2 Relaxation Scheme . . . 90
4.5.3 Residuals . . . 91
4.6 Remarks on Numerical Stability and Convergence . . . 92

5 Verification and Validation Cases **96**
5.1 Verification . . . 96
5.2 Developing Flow in a Curved Rectangular Duct . . . 100
5.3 Flow in a Sharply Curved Channel . . . 108
5.4 Flow in a 270° Bend with Moderate Curvature . . . 120
5.5 Flow in an S-Shaped Trapezoidal Channel . . . 131

6 River Application **139**
6.1 Introduction . . . 139
6.2 Numerical simulation . . . 144
6.2.1 RSim-3D . . . 144
6.2.2 SSIIM . . . 146
6.2.3 FLUENT . . . 147
6.2.4 Comparison . . . 149
6.3 Results . . . 152
6.3.1 Water surface . . . 152
6.3.2 Depth-averaged flow velocities . . . 159
6.3.3 Secondary flow . . . 163
6.4 Summary . . . 166

7 Conclusions and Future Work **168**
7.1 Conclusions . . . 168
7.2 Future Work . . . 169

Bibliography **171**

A Flow charts and examples **A.1**

B Velocity profiles **B.1**