Advanced Computation in Fluid Mechanics
Course PM

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Description

Advanced trans-disciplinary course approaching fundamental problems in fluid mechanics of major practical importance by advanced tools from mathematical analysis and numerical analysis, using modern computational technology.

Prerequisites

The course DN2260 Finite element methods, or equivalent.

Aim

The goal is that the students should be able to analyze and use General Galerkin (G2) adaptive finite element computational technology to model fluid flow at high Reynolds numbers. More precisely, the students should be able to:

- define the concepts weak solution and weak uniqueness
- derive energy estimates for underlying equations and G2 approximations
- derive a posteriori output error estimates for G2 using duality
- analyze the global effect of friction boundary conditions in G2
- use G2 software for adaptive flow computations with error control

Based on a critical review of research literature and the students own G2 computations, the student should be able to compare state of the art fluid mechanics with G2 computation/analysis concerning the following fundamental problems:

- turbulence and basic mathematical models
- boundary conditions and flow separation
- aerodynamics and generation of drag and lift

with applications in a number of areas such as car-, ship- and aircraft industry. The purpose is to develop a critical approach with the possibility to question established truths, and to form new hypotheses.

Examination

Exam (4.0 hp)

- Problems 1-10 (1 single pdf-file): Monday 8.00 March 16 (45%)
- Referee report (1 page, single pdf-file): Monday 8.00 May 4 (10%)
- Final report (8 pages, single pdf-file): Monday 8.00 May 11 (45%)
- Oral presentation of final report: last meeting (pass/fail)

Project (3.5 hp)

- Project report (5 pages as one single pdf-fil): Monday 8.00 April 6 (25%)
- Review 1 (1 page as single pdf-file): Monday 8.00 April 13 (25%)
- Review 2 (1 page as single pdf-file): Monday 8.00 April 20 (25%)
- Review 3 (1 page as single pdf-file): Monday 8.00 April 27 (25%)

Each part of the examination is mandatory to pass the course. All submissions should be by email to the course leader in time for the deadlines, and the only accepted format is pdf-files. The percentages refer to the respective weights the activities have for the total grades (for *Exam* and *Project*). The quality of each activity is then also graded by the course leader, so that the total grade is given as the sum of the percentages times the quality (0-100%) of each activity. The total grade for the Exam and Project is given according to the following scale:

- A 90%
- B 80%
- C 70%
- D 60%
- E 50%
- F <50% Failure to comply with deadlines for submissions automatically reduces the quality of the activity.

Course plan

Seminars once per week:

- Seminar 1
  - Topic: thermodynamics, incompressible flow, stability, vorticity
  - Problem sheet: 1-4
  - Reading: [1] (chapters 1-12)

- Seminar 2
  - Topic: General Galerkin (G2) method, skin friction boundary conditions
  - Problem sheet: 5-7
  - Reading: [1] (chapters 28)
- Seminar 3
  - Topic: linearized dual problem, a posteriori error estimation, adaptive method
  - Problem sheet: 8-10
  - Reading: [1] (chapters 30,33)
- Seminar 4
  - Topic: finite element software, intro to project, intro to FEniCS
- Seminar 5
  - Topic: turbulence, blowup of Euler solutions, Clay $1 million Prize
- Seminar 6
  - Topic: d'Alembert paradox, boundary conditions, flow separation
- Seminar 7
  - Topic: aerodynamics, drag and lift generation, flying
- Seminar 8
  - Presentations of final report

Course literature

J. Hoffman and C. Johnson (2007) *Computational Turbulent Incompressible Flow*, and a number of scientific papers (to be handed out at course start).

References

[1] J. Hoffman and C. Johnson, *Computational Turbulent Incompressible Flow: Applied Mathematics Body and Soul Vol 4*, Springer-Verlag Publishing, 2006.

Contact

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