KEB-45250 Numerical Techniques for Process Modeling
Assignment Blasius boundary layer

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Introduction

Blasius boundary layer has a well known analytical solution. In this assignment, the same case is solved using finite volume method and a custom code and use the analytical solution for validation.

The assumed language is Python. If you wish to use some other language, ask before starting the assignment.

The simplified governing equations of the Blasius boundary layer are

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$\rho \left(u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right) = \mu \frac{\partial^2 u}{\partial y^2} \tag{2}$$

The boundary layer is rather straight forward to solve because we can ignore the pressure gradient. Many other terms are also ignored during the derivation of Eqs. 1 and 2. You may include them in the finite volume solution or ignore them.

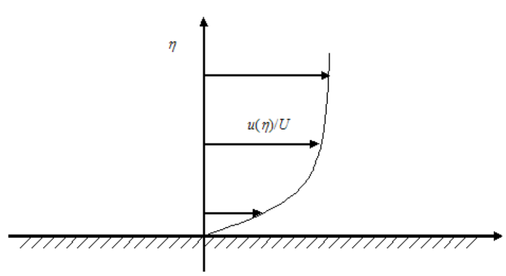

Figure 1: Blasius boundary layer

The analytical solution is explained, for example, here https://www.calpoly.edu/~kshollen/ME347/Handout

The Blasius boundary layer is well known and it should be easy to find references. It is recommended to use them. Just remember to cite the sources.

Provided files

- Validation calculation file
  - analyticalBlasius.py

Returning a report

Deadline Sunday 29.03. at 23:55.

Return the report by email to antti.mikkonen@tut.fi. I will send a answer email withing 24 hours. If you receive no such email, assume that something went wrong.

Requirements for the report

- Running, parametrized code with validation
  - It is required that you have written the code by yourself.
- Validation with analytical solution in a couple of cases and at different locations of the domain.
- Mesh independency study
- Governing equations
- Discretized governing equations
  - If you use the same methods for multiple terms, there is no need to repeat them all
- Discretization methods

Course grading

- Exam
  - must be passed, grading 0-5
  - 60% weight
- Assignment I
  - must be passed, grading 0-5

- 25% weight
- CFD
- Two options (one must be done)
  - NACA 0012 validation case
  - Python FVM solution of Blasius boundary layer
  - If you do both, you can get 5-10% extra
- The report must be completed in time
  - Late, acceptable return results in grade 1
- Returned report may be
  - accepted
    - grading 1-5
  - accepted with corrections
    - after corrections, grading 0-5
  - failed with corrections
    - after corrections, grade 0-1
  - failed
    - grade 0

- Assignment II
  - must be passed, grading 0-5
  - 15% weight

Bag of tricks

- The flow will require some space to develop. Use a large enough domain.
- I would highly recommend learning to use scientific writing tools. I personally recommend LyX. Equations are easy to write. Figures are automatically updated. Cross references, citations, section numbers, etc. are automatically updated.

LyX equation example

LyX makes scientific writing a lot easier. It has all the power of LaTeX with a easy to use graphical interface. If you open this file in LyX, you will see the Eq. 3 in a very similar format as in this pdf.

$$\frac{\partial\rho\mathbf{u}}{\partial t}+\nabla\cdot(\rho\mathbf{u}\mathbf{u})=\nabla\cdot\boldsymbol{\tau}-\nabla p+\mathbf{f}_{b} \tag{3}$$

The following is the raw LaTeX code for the same equation.

```
\frac{\partial\rho\mathbf{u}}{\partial t}
+\nabla\cdot\left(\rho\mathbf{uu}\right)
=\mathbf{\nabla}\cdot\bm{\tau}
-\nabla p+\mathbf{f}_{b}
```

Reference to the equation 3.