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Luleå Tekniska Universitet
F7024T Multifysik, simulering och beräkning

Assignment 3: Fluid flow past cylinder. Drag and lift forces

With supervisor
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Abstract

This work contains the result and analysis of the third COMSOL-laboratory exercise where the drag and lift force of a fluid, in this case water, on a cylinder has been simulated. It is found that the drag coefficient decreases logarithmically drastically compared to the Reynold number, going from $C_D \approx 200$ to $C_D \approx 3$ between $Re = 0$ and $Re = 50$, see fig. 1. Compared to wind tunnel data the drag coefficient seems to start at a higher value for low Reynold numbers, but decreased faster. System did not converge for Reynold numbers much higher than 300, which is around where the system should change from laminar to turbulent flow[a].
Secondly, introducing a rotation speed Ω, a negative linear dependency between the lift coefficient C_L and the dimensionless coefficient $Q = \frac{\Omega a}{V_\infty}$ could be observed. The linear plot started at $C_L = 0$ for $Q = 0$, and decreases[b] with ≈ 7 for each increase in the rotational coefficient Q.

[a]Derived from the only table at [2]

[b]Note that the negative sign only determines the rotation direction and is of little importance.

1 Introduction

COMSOL Multiphysics® is a general-purpose software platform, based on advanced numerical methods. It is a powerful tool useful to simulate flows; fields; forces and such in models provided either by files or built directly in COMSOL.

This report is a part of a written documentation of the COMSOL-laboratory exercises made in the course Multiphysics, Simulation and Computation at Luleå University of Technology. These exercises serve as practice in formulating mathematical models to describe physical and technical problems in a way that is suitable for implementation of the finite element method.

This work contains the result and analysis of the third COMSOL-laboratory exercise where the drag and lift force of a fluid, in this case water, on a cylinder has been simulated. This is done in two distinct studies.

In the first study the drag force will be simulated in which there will be no rotational speed on the affected cylinder. In this study the inflow speed, V_∞, will be a function of the Reynold number, see eq. (1), to easily perform parametric sweeps. The drag coefficient C_D can be calculated using eq. (2), where F_D is the drag force extracted by COMSOL, A_{proj} the area projected in the direction of the stream. The assignment is to look how the Reynolds number affects the drag coefficient.

$$Re = \frac{V_\infty 2a\rho}{\mu} \tag{1}$$

$$C_D = \frac{2F_D}{\rho V_\infty^2 A_{proj}} \tag{2}$$

The second study will introduce a rotational velocity, Ω, to the affected cylinder. This will generate an lift force on the water surrounding the cylinder. A lift coefficient can be calculated using eq. (3) where F_D is the lift force

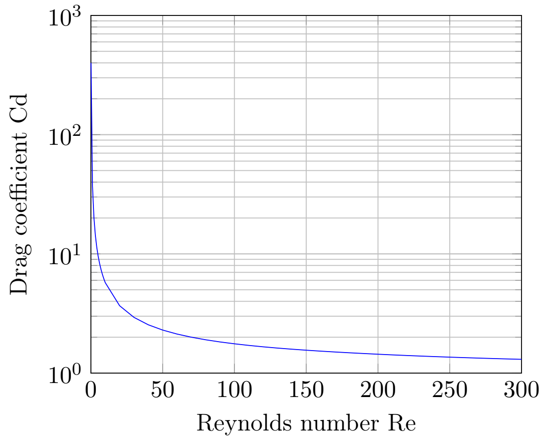

Figure 1: Drag coefficient compared to Reynold number

and is calculated using eq. (4).

$$C_L = \frac{2F_L}{\rho V_\infty^2 A_{proj}} \tag{3}$$

$$F_L = \rho V_\infty \Omega 2\pi a^2 \tag{4}$$

2 Results

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3 Discussion and closing words

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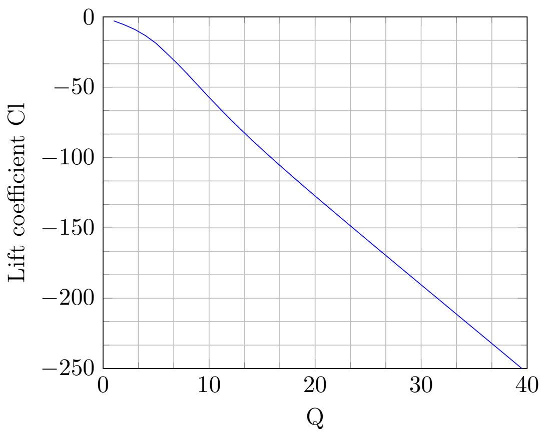

Figure 2: Lift coefficient compared to $Q = \frac{\Omega a}{V_\infty}$

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References

[1] Hans Åkerstedt, Multiphysics F7024T, Assignment #3a, *Fluid flow past cylinder. Drag and lift forces*, rev. 2017-03-27.

[2] *Water Flow in Tubes - Reynolds Number*, The Engineering Toolbox, `\url{http://www.engineeringtoolbox.com/reynold-number-water-flow-pipes-d_574.html}`