DNS study of flow over periodic hills with Reynolds number
up to 10595

Dr.-Ing. Yoshiyuki Sakai†
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† Chair of Hydromechanics, Technical University of Munich, 80333 Munich, Germany.
Email: yoshiyuki.sakai@tum.de

Background

The prediction of flow separation from curved surfaces and subsequent reattachment is a fundamentally challenging problem: It exhibits highly irregular movements of separation and reattachment lines, strong influence from the outer flow, qualitative transition from a boundary layer-type to a separated shear layer-type flow where law-of-the wall and standard model assumptions for either attached flows or free shear layers fail to capture the phenomena correctly. Generating reliable benchmark data of such class of flow is, therefore, highly valuable for the purpose of improving and/or evaluating the quality of the turbulence models used for Reynolds-averaged Navier–Stokes (RANS) or large-eddy simulations (LES), in other words for the engineering applications.

Flow over periodically arranged hills was proposed by Mellen et al. [2000], and carefully designed to include the above key flow features whilst having a relatively simple domain with well-defined boundary conditions that allow us to compute at an affordable cost. Consequently, the periodic hill case has established itself as one of the standard benchmarks to test turbulence and related models, e.g. Davidson [2003], Fröhlich et al. [2005], Fröhlich and von Terzi [2008], Ziefle et al. [2008], Xiao and Jenny [2012], Xiao et al. [2013].

Breuer et al. [2009] reported the PIV measurement data of the flow with the hill-height ($H$) based Reynolds number $Re_H = 5600$ and 10595, as well as the numerical dataset of $Re_H = 700 – 10595$ which was generated by means Direct Numerical Simulations (DNS, up to $Re_H = 5600$), and wall-resolved LES ($Re_H = 10595$). This study serves as a standard reference for that purpose until present date.

Subsequently, Rapp and Manhart [2011] conducted further experimental investigation with Reynolds number ranging between 10600 and 37000 using PIV and LDA measurement techniques. They observed an increasing degree of mean streamwise velocity overshoot directly above the hill crest with increasing Reynolds number (their Fig. 8). More recently, Krank et al. [2018] conducted DNS simulation of the flow at $Re_H = 10595$ using the code based on 7th and 8th-order incompressible discontinuous Galerkin method. The new numerical result, however, shows a significant discrepancy in the streamwise velocity overshoot directly above the hill, with respect to the above experimental studies (their Fig. 6 and 8).

The purpose of this project is to perform new periodic hills DNS simulation with $Re_H = 10595$ using our in-house code MGLET. Careful comparison should then be made with the experimental data of Breuer et al. [2009], Rapp and Manhart [2011] and numerical data of Krank et al. [2018], with special focus on the streamwise velocity overshoot above the hill crest. It is also of our interest to report the possible efficiency improvement in MGLET simulations due to the progress that has been made since the last study, such as newly-developed external grid generator, as well as parallel-scaling optimisation (cf. Sakai et al. [2019]).
Tasks

• conduct literature review on numerical and experimental studies of flow over periodic hills
• learn how to use our in-house CFD code MGLET
• set up and run simulation with $Re = 5600$ for validation purpose
• validate the results against the previous DNS and the experimental data presented in Breuer et al. [2009]
• set up simulation and run the flow at $Re = 10595$
• compare the simulation results with the DNS data of Krank et al. [2018], and the experimental data of Breuer et al. [2009], Rapp and Manhart [2011]
• compare the results with the unpublished data from near-wall measurements conducted as a follow-up of Rapp and Manhart [2011]

Required skills

• basic knowledge in fluid dynamics and CFD
• basic knowledge in UNIX/Linux system
• experience in scripting languages (e.g. MATLAB, Python, R)
• sufficient communication skill in English
• patience to work with research code written in FORTRAN 77/90

Recommended skills

• basic knowledge in compiled languages (e.g. FORTRAN, C/C++)
• experience in CFD application (e.g. OpenFOAM, Fluent)

Benefits for applicant

• in-depth supervision in turbulence research
• practical experience in CFD
• practical experience in scientific and high-performance computing

Contact

Dr.-Ing. Yoshiyuki Sakai
Associate Professorship of Hydromechanics
Technical University of Munich (TUM)
Arcisstr. 21, 80333 Munich, Germany
Tel: +49 (0)89 289 25278
Email: yoshiyuki.sakai@tum.de
References


