Research Report（April, 2020 - March, 2023）

In the SGU course of Mathematical Physical Science: April 2020-March 2023

Conferring university	Degree name	Date of conferment
Waseda University	博士（工学）課程	03/23/2022

Enrollment from April 2020   Department of Modern Mechanical Engineering   LIU YANG

I. List of Papers

- **Yang Liu**, K. Takizawa, Y. Otoguro, T. Kuraishi, and T.E. Tezduyar, "Flow Computation with the Space–Time Isogeometric Analysis and Higher-Order Basis Functions in Time", *Mathematical Models and Methods in Applied Sciences*, published online, (2022), doi:10.1142/S0218202522500579

- **Yang Liu**, K. Takizawa, T.E. Tezduyar, T. Kuraishi, and Y. Zhang, "Carrier-Domain Method for High-Resolution Computation of Time-Periodic Long-Wake Flows", *Computational Mechanics*, published online, (2022), doi10.1007/s00466-022-02230-6

- 山崎 智司, **劉 洋**, 張 雨菲, 倉石 孝, 滝沢 研二, Tayfun E. Tezduyar, "複数風車の後流解析のための効率的な計算手 法 の構築", 計算工学講演会論文集, 25 (2020).

- **劉 洋**, 山崎 智司, 張 雨菲, 倉石孝, 張 福林, 滝沢 研二, Tayfun E. Tezduyar, "Multi-Domain Computation of Wind Turbine Wake Flows", 日本機械学会 2020 年度年次大会, 20 (2020).

- **劉 洋**, 滝沢 研二, TayfunE.Tezduyar, 倉石 孝, 張 雨菲, "Carrier-DomainMethod(CDM)による時間周期的後流の 高精度計算", 第 36 回数値流体力学シンポジウム, (2022).

II. Record of Awards

36th Computational Fluid Dynamics Symposium : The Best CFD Graphics Award

III. List of Talks

- **Yang Liu**, K. Takizawa, T.E. Tezduyar, T. Kuraishi, and Y. Zhang, "Carrier-Domain Method for High-Resolution Computation of Time-Periodic Long-Wake Flows", *in Proceedings of the International workshop on Bifurcation Governed by Partial Differential Equations,* Tokyo, Japan, 2022.

- **劉洋,** 山崎智司,張雨菲,倉石孝,張福林,滝沢研二, Tayfun E. Tezduyar, "Multi-Domain Computation of Wind Turbine Wake Flows", 日本機械学会 2020 年度年次大会, 20 (2020).

- **劉洋,** 滝沢研二,TayfunE.Tezduyar, 倉石孝, 張雨菲, "Carrier-DomainMethod(CDM)による時間周期的後流の 高精度計算", 第 36 回数値流体力学シンポジウム, (2022).

IV. Research Results in AY 2022

In 2022, we proposed the Carrier-Domain Method (CDM) to reduce the computational cost of wind turbine long-wake flow analysis. We introduced two versions of CDM, where the computational domain (CD) moves in a continuous fashion (CDM-C) and the computational domain moves in a discrete fashion (CDM-D). We gave computation examples with the CDM-D on 2D flow past a circular

cylinder at Reynolds number 100 (see Figure 1), and with CDM-C on 3D flow past a circular cylinder at Reynolds number 100. After that, we gave engineering applications on the wind turbine long-wake flow analysis at High Reynolds number (see Figure 2).
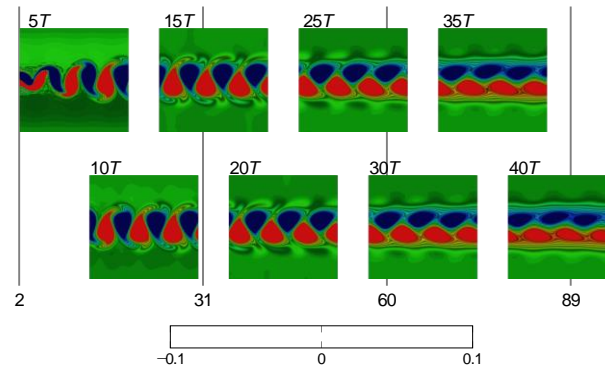

Figure 1: 2D cylinder long-wake flow. Instant vorticity obtained from CDM-D computation. The CD at different integer time-period (*T*), colored by vorticity
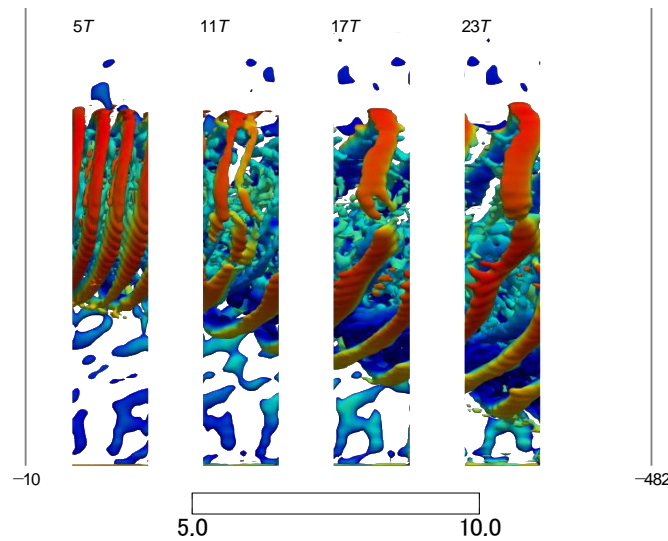

Figure 2: 3D wind turbine long-wake flow. Instant isosurfaces corresponding to a positive value of the second invariant of the velocity gradient tensor obtained from CDM-C computation. The CD at different integer T, colored by velocity magnitude

V. Summary (From April 2020 to May 2023)

I am grateful to SGU, which provided me the opportunity to study aboard and to get instructed by researchers at top global universities in the area I focused on. During the three years of study, the CDM was successfully proposed with inspiring innovations for high-resolution computation of long-wake flows. The CDM has both the cost-effectives needed to make the computations practical and the accuracy needed in the long-wake computations to correctly represent the vortex patterns far downstream. We demonstrated how the CDM works by computing, with the CDM-C and CDM-D, 2D flow past a circular cylinder at Reynolds number 100. Beyond that, we gave limitations on how to choose computational domain moving speed and computational domain length in the CDM. We also demonstrated that, with the CDM-C, 3D long-wake flows behind a circular cylinder as well as the wind turbine long-wake flows at high Reynolds number could be accurately resolved with less computational cost. The results showed the power of CDM in high-resolution computation of time-periodic long-wake flows.