

MEXT Program for Promoting Researches on the Supercomputer Fugaku, Leading research on innovative aircraft design technologies to replace flight test

Report Number: R22ECMP30

Subject Category: Competitive Funding

URL: <https://www.jss.jaxa.jp/en/ar/e2022/20783/>

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● **Abstract**

Realization of high-precision aerodynamic prediction by high-fidelity LES analysis around whole aircraft configuration for actual flight conditions.

Ref. URL: <http://www.klab.mech.tohoku.ac.jp/fugaku/index.html>

● **Reasons and benefits of using JAXA Supercomputer System**

It is possible to develop programs efficiently because JSS has the same architecture as the final target "Supercomputer Fugaku",

● **Achievements of the Year**

In the analysis method that combines the hierarchical cartesian grid method and the immersed boundary method (IB method), the movement and deformation of the object can be handled relatively easily because the shape of the object is expressed as an algorithm. Therefore, we constructed a method for analyzing the flow around a moving object, and confirmed that the same analysis as the conventional analysis around a fixed object can be performed (Fig. 1, 2). On the other hand, there is also the problem that the conservation law is not strictly satisfied in the vicinity of the object, and as a result of actually performing an analysis in a closed system (Fig. 3), it was confirmed that the total mass was not conserved. From the point of view of the finite volume method, we clarified that the reason for this is that the cell face areas shared by adjacent cells are not considered equally. Therefore, we proposed a modified method and confirmed that the proposed method conserves total mass in the closed system (Fig. 4).

A overset grid was created by oversetting a BCM grid and a layer grid for the flow analysis around an aircraft high-lift configuration which has complicated geometry. It took dozens of hours of calculation time to create

overset information, but the calculation time was shortened by appropriately setting the search range of cells to be interpolated.

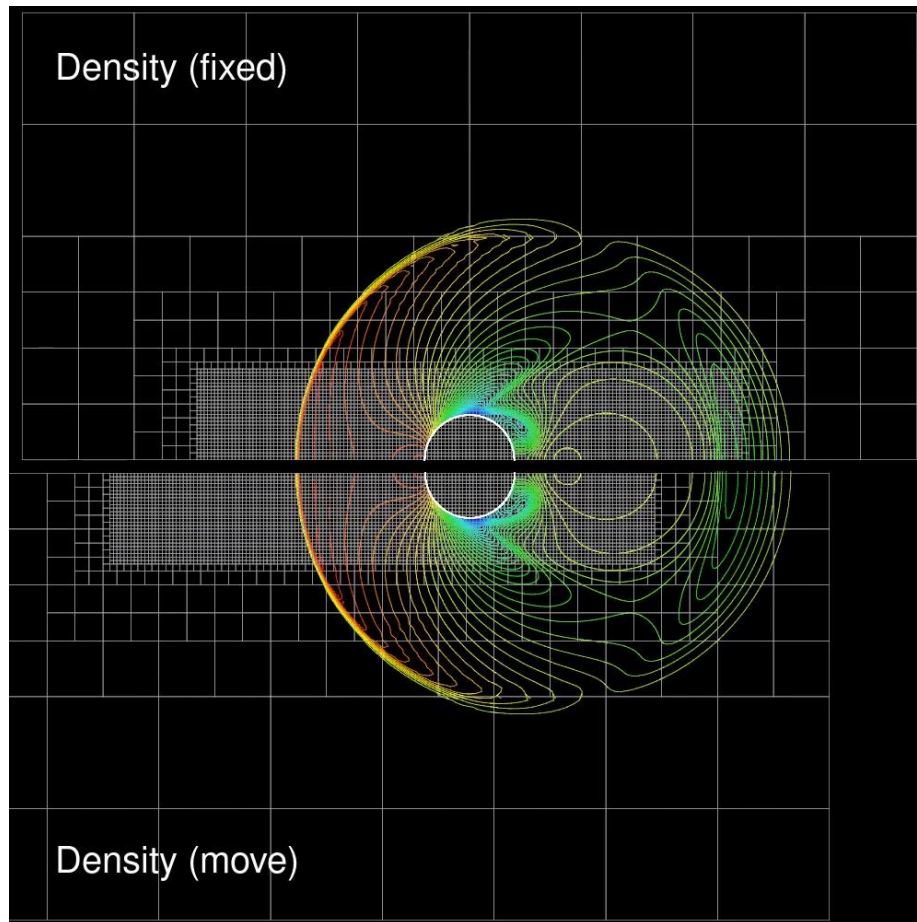


Fig. 1: Comparison of spatial density distributions in results for flow around a moving cylinder in stationary fluid and a fixed cylinder in uniform flow. Good agreement was obtained between the two methods. (Video. Video is available on the web.)

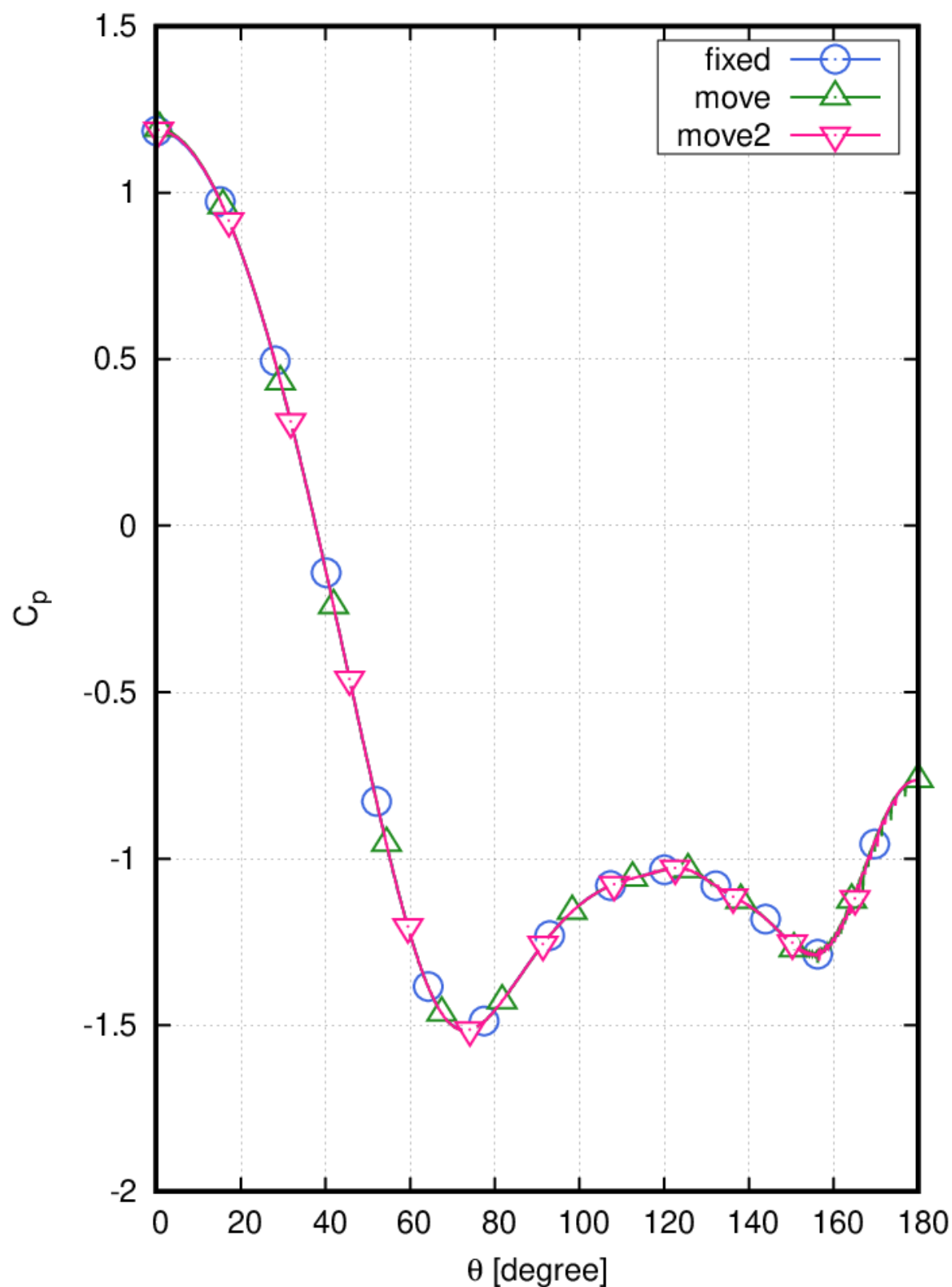


Fig. 2: A comparison of the cylinder surface pressure coefficient distribution in the results for the flow around a moving cylinder in stationary fluid and a fixed cylinder in uniform flow. fixed: free stream Mach number is 0.5, cylinder is fixed. move: free stream Mach number is 0.0, cylinder moving Mach number is -0.5, move2: free stream Mach number is 0.25, cylinder moving Mach number is -0.25. The surface pressure coefficient distributions are in good agreement in all cases.

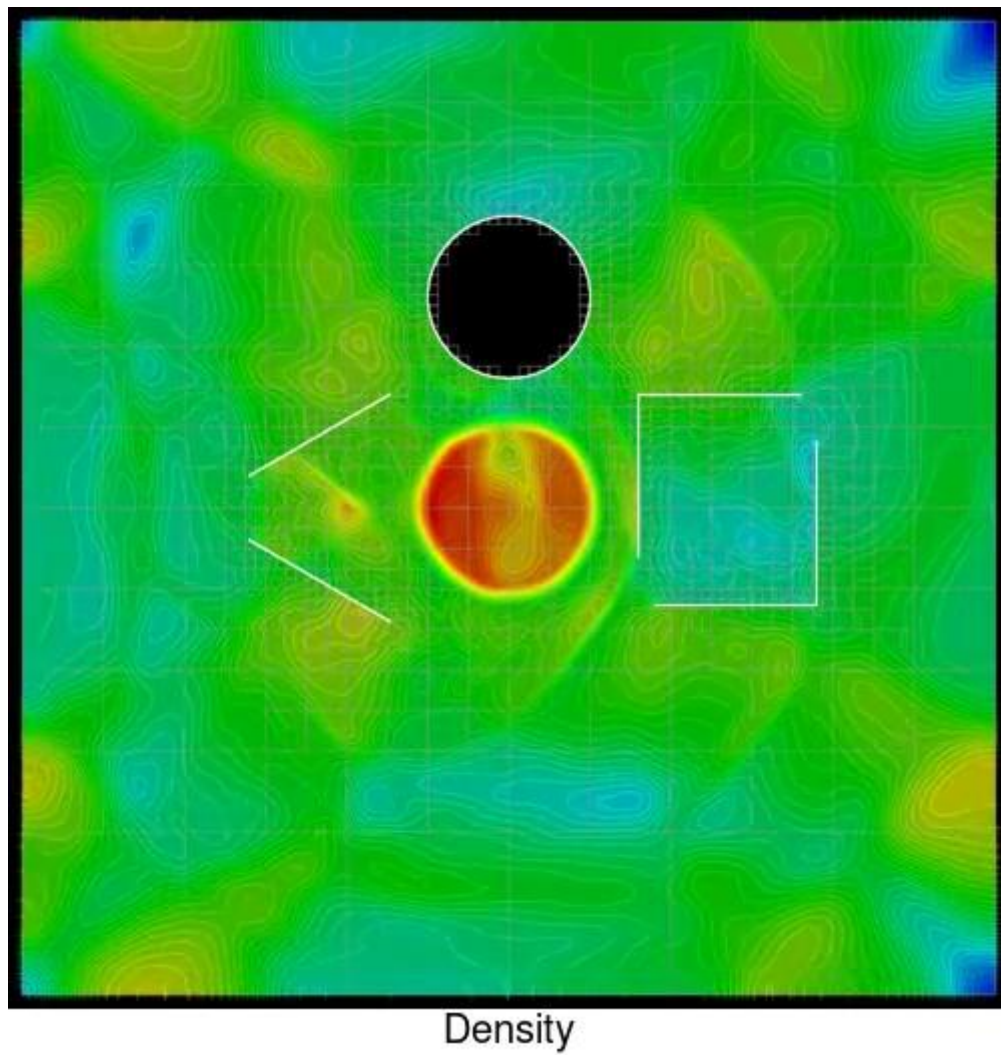


Fig. 3: Analysis in a closed system: Analysis in which pressure waves are generated and propagated from the center of a computational area surrounded by walls, where thin plates and cylinders are arranged. The mass of the whole system is always constant because there is no mass inflow and outflow.

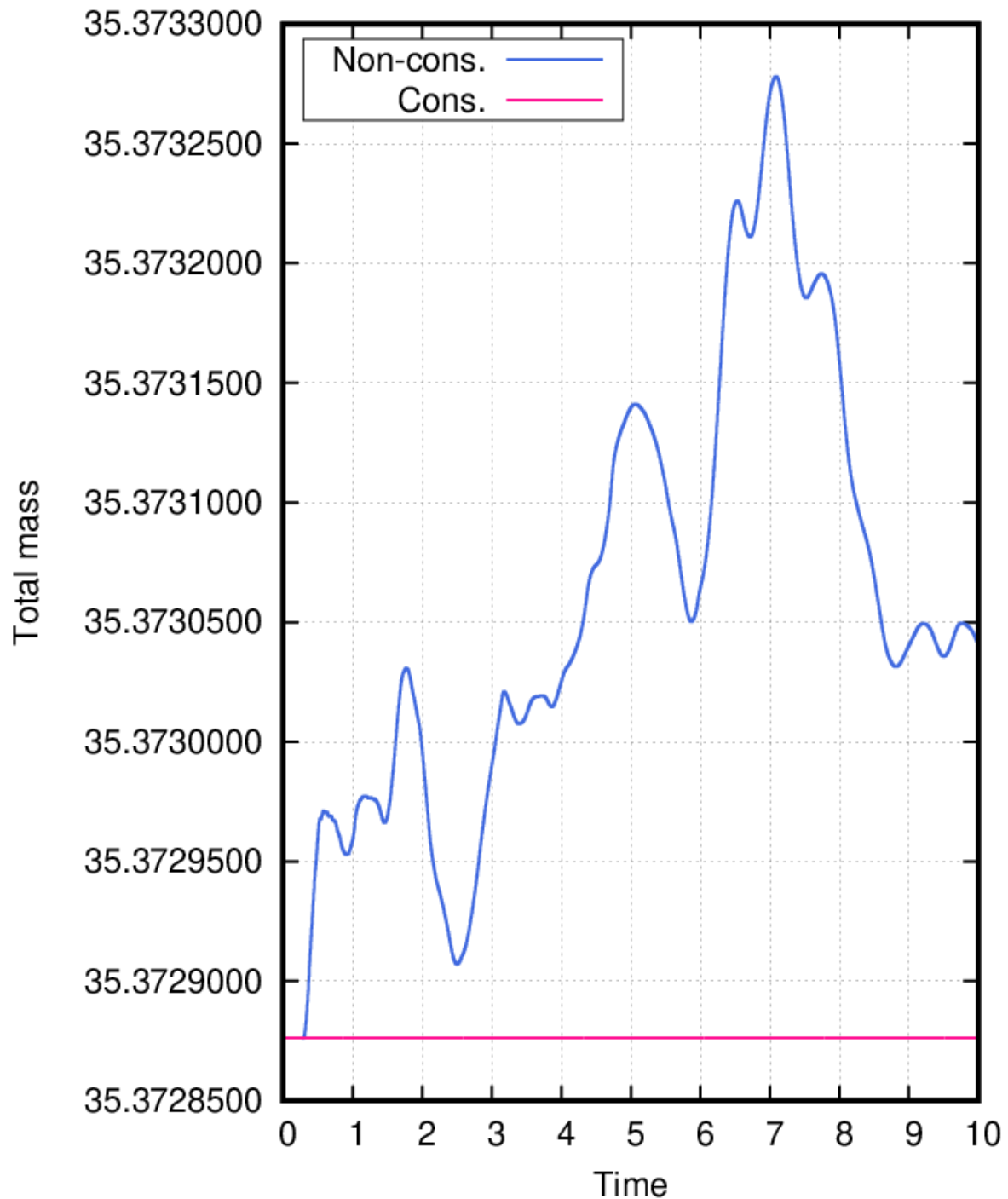


Fig. 4: Result in a closed system: Although the total mass fluctuates in the analysis that does not satisfy the conservation laws, the proposed method keeps the mass constant on the order of machine 0.

Publications

- Non peer-reviewed papers

1) Ryoji Takaki, Analysis of flow around moving bodies using the immersed boundary method, Proceedings of the 3rd Workshop on Cartesian Grid-based CFD, JAXA-SP-22-008, pp77-82, 2023.

- Invited Presentations

1) Ryoji Takaki, Toward realization of aerodynamic characteristic evaluation technology under actual flight conditions of aircraft, 5th Advanced Simulation Seminar 2022, 2022.

- Oral Presentations

1) Ryoji Takaki, Analysis of flow around moving bodies using the immersed boundary method -3rd Workshop on Cartesian Grid-based CFD -, 54rd Fluid Dynamics Conference/40th Aerospace Numerical Simulation Symposium, 3C05, 2022.

2) Ryoji Takaki, Study on conservation of immersed boundary method, 36th Computational Fluid Dynamics Symposium, B04-1, 2022.

3) Ryoji Takaki, Analysis accuracy near object surface in hierarchical cartesian grid method, FY2022 Aerospace Symposium, 1L13, 2023.

- Other

1) Ryoji Takai, Application Development in the Post-Fugaku Era, Program for Promoting Researches on the Supercomputer Fugaku, 6th HPC Monozukuri Workshop Panel Discussion "Results and Practical Applications in the Era of Fugaku and Prospect in the Era of the Post-Fugaku", 2022.

● Usage of JSS

● Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	1 - 40
Elapsed Time per Case	50 Hour(s)

● JSS3 Resources Used

Fraction of Usage in Total Resources*1(%): 0.84

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	21,930,894.99	0.96
TOKI-ST	22,672.80	0.02
TOKI-GP	390.14	0.02
TOKI-XM	9,985.48	6.25
TOKI-LM	49,190.14	3.30
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage* ² (%)
/home	772.28	0.70
/data and /data2	43,428.61	0.33
/ssd	2,060.28	0.29

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage* ² (%)
J-SPACE	3.21	0.01

*¹: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*²: Fraction of Usage : Percentage of usage relative to each resource used in one year.

● ISV Software Licenses Used

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage* ² (%)
ISV Software Licenses (Total)	0.93	0.00

*²: Fraction of Usage : Percentage of usage relative to each resource used in one year.