Research and development of fluid analysis tools using GPUs for stall and buffet research

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Abstract

Acceleration of FaSTAR-GPU code for large scale simulations of full aircraft configuration at flight Reynolds number on GPUs. Fundamental research of transonic airfoil buffet using the OpenSBLI DNS solver on GPUs.

Reasons and benefits of using JAXA Supercomputer System

Development and acceleration of GPU-enabled FaSTAR in preparation for JSS4. GPU nodes are used to perform large scale simulations for aircraft stall and buffet research applications.

Achievements of the Year

FaSTAR-GPU: The main FaSTAR branch was upgraded with OpenACC support for multi-GPU execution. Validation was performed against the CPU version of the code with good agreement. Speed-up of 3x was achieved compared to typical CPU setup. Full aircraft stall RANS simulations (figure 1) were performed up to flight Reynolds number (30 million) for the first time at JAXA.

OpenSBLI: The OpenSBLI DNS solver was used on up to 128 GPUs to perform world first high-fidelity simulations of turbulent transonic buffet on wide-span wings (figure 2). 3D buffet effects were identified and analysed with spectral proper orthgononal decomposition methods (SPOD). Three journal papers were published on this fundamental research topic.

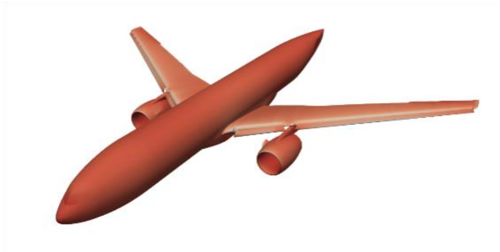

Fig. 1: Full aircraft CRM-HL stall simulations up to flight Reynolds number of Re=30 million using FaSTAR-GPU on TOKI-RURI JSS3 GPU nodes.

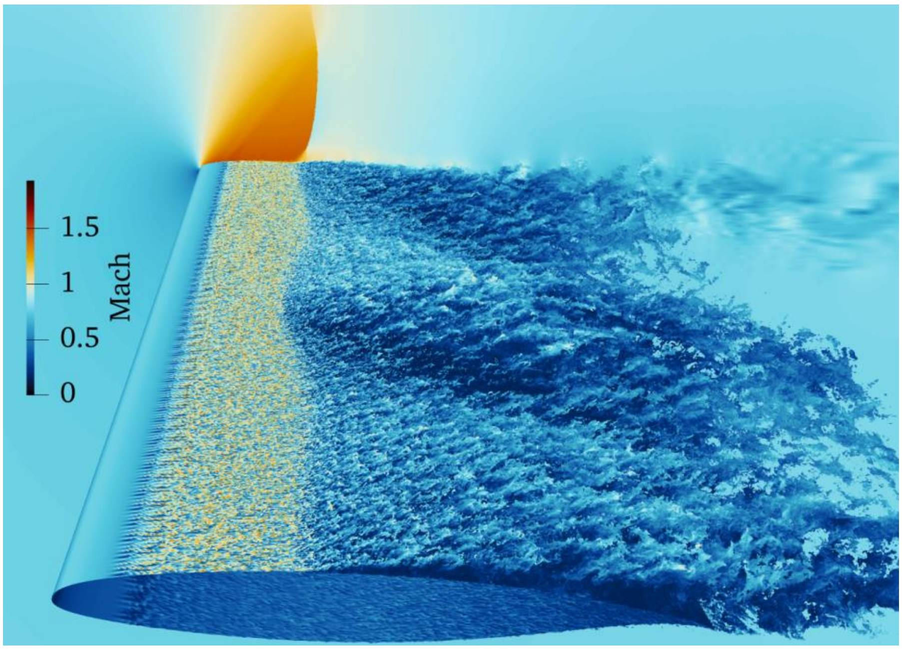

Fig. 2: Wide-span transonic buffet simulations of NASA-CRM wings up to aspect ratio 3, using the TOKI-RURI JSS3 GPU nodes.

Publications

- Peer-reviewed papers

[1] DJ Lusher, A Sansica, A Hashimoto. Effect of Tripping and Domain Width on Transonic Buffet on Periodic NASA-CRM Airfoils. AIAA Journal 62 (11), 4411-4430 (2024).

[2] DJ Lusher, A Sansica, ND Sandham, J Meng, B Siklósi, A Hashimoto. OpenSBLI v3.0: High-fidelity multi-block transonic aerofoil CFD simulations using domain specific languages on GPUs. Computer Physics Communications 307, 109406 (2025).

[3] D.J. Lusher, A. Sansica, A. Hashimoto. Implicit large eddy simulations of three-dimensional turbulent transonic buffet on wide-span infinite wings. Journal of Fluid Mechanics (2025).

- Non peer-reviewed papers

[1] D.J. Lusher, A. Sansica, A. Hashimoto. Domain specific languages for improved performance, productivity, and portability in computational fluid dynamics applications. ANSS conference, Kagoshima, 2024.

[2] M. Zauner, D.J. Lusher, P. Moise, A. Sansica, A. Hashimoto, N.D. Sandham. Open-Source Parametric Airfoils to Study Geometric Effects on Buffet. AIAA Aviation Forum, Las Vegas, 3508 (2024).

[3] N.D. Sandham, P.K. Sharma, D.J. Lusher. Linear and nonlinear response of high-speed boundary layers to continuous stochastic forcing. IUTAM transition symposium, Nagano (2024).

- Invited Presentations

[1] D.J. Lusher, A. Sansica, A. Hashimoto. High-fidelity study of three-dimensional turbulent transonic buffet on wide-span infinite wings. NASA Langley Research Center, Virginia, July 2024.

- Oral Presentations

[1] D.J. Lusher, A. Sansica, A. Hashimoto. Domain specific languages for improved performance, productivity, and portability in computational fluid dynamics applications. ANSS conference, Kagoshima, 2024.

[2] D.J. Lusher, A. Sansica, A. Hashimoto. Numerical Study of Laminar, Transitional, and
Turbulent Shock-Buffet on Supercritical Aerofoils. IUTAM transition symposium, Nagano (2024).

Usage of JSS

- **Computational Information**

Process Parallelization Methods	GPU
Thread Parallelization Methods	N/A
Number of Processes	128
Elapsed Time per Case	100 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 2.91

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	465,798.92	0.02
TOKI-ST	14,477.56	0.01
TOKI-GP	6,083,208.48	93.55
TOKI-XM	0.00	0.00
TOKI-LM	14,981.33	1.08
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	1,112.73	0.75
/data and /data2	111,303.17	0.53
/ssd	31,994.92	1.71

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	7.06	0.02

[*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)	46.45	0.03

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