Application of High-Fidelity Aerodynamic Analysis to Multidisciplinary Design Optimization for Reusable Space Transportation System

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Abstract

Strong interactions between vehicle and trajectory during the design of winged reusable space transportation systems have motivated the application of multidisciplinary design optimization methodologies. However, low-fidelity aerodynamic analysis methods such as an engineering-level panel code have been used in our previous research, which poses the issues of accuracy.

In this study, the theoretical and practical applicability of FaSTAR, a CFD code developed by JAXA, to the system optimization of suborbital space planes will be investigated. Aerodynamic characteristics of the obtained design solutions will be evaluated in detail by using JAXA FaSTAR as well.

Ref. URL: https://space-systems.me.noda.tus.ac.jp/en/research-en/system-optimization/

Reasons and benefits of using JAXA Supercomputer System

High-performance computing environments such as supercomputers are essential in high-fidelity design optimization of space transportation systems, since aerodynamic characterization of a variety of vehicle shapes is required for the wide range of Mach numbers and angles of attack. JAXA FaSTAR and its related software are suited to the present study due to their computational efficiency and automation capability. These advantages can be gained more by using the JAXA supercomputer system, for which they are tuned.

Achievements of the Year

In the fiscal year 2020, co-Kriging surrogate models were developed in order to realize accurate aerodynamic characterization with reduced computational cost, and they were incorporated into the multidisciplinary design optimization framework of manned suborbital space planes. By adding as few as 2 data points calculated by JAXA FaSTAR to 150 data points obtained from an in-house panel code, the prediction accuracy of the surrogate models has improved significantly. Multidisciplinary design optimization including the constructed surrogate models was performed by using the hybrid methodology of a multi-objective evolutionary algorithm and a gradient-based optimizer, and a variety of Pareto optimal solutions were obtained.

In parallel, extensive aerodynamic evaluations of a vehicle shape optimized for an unmanned suborbital space plane in our previous study were conducted.

Publications

N/A

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	120 - 160
Elapsed Time per Case	1 Hour(s)

- **Resources Used(JSS2)**

Fraction of Usage in Total Resources*1(%): 0.08

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
SORA-MA	461,585.19	0.09
SORA-PP	157.82	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	52.45	0.05
/data	524.52	0.01
/ltmp	10,742.19	0.92

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.00	0.00

[*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.

- **Resources Used(JSS3)**

Fraction of Usage in Total Resources[*1](%): 0.07

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	353,228.09	0.08
TOKI-RURI	0.00	0.00
TOKI-TRURI	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	33.38	0.02
/data	333.79	0.01
/ssd	333.79	0.17

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.00	0.00

[*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.