Numerical Simulation of Rocket Turbopumps

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● **Abstract**

Turbopumps are still one of key components in liquid rocket engine development in terms of cost, time, and risks. Furthermore, a turbopump itself is a complex system consisting of sub-components such as pump, turbine, bearing, balance piston, sealing and so on. From numerical simulation technology point of view,　there is no technology able to evaluate performance of an entire turbopump system in the world. And also, accuracy and fidelity of numerical simulation technology for sub-components are still poor and cannot be used to reduce the number of　experiments. Therefore, experiments are indispensable to evalute feasibility of considered design in engine development.

In this study, numerical simulation technology of an entire turbopump system able to be applicable in engine design phase has been developed enhancing accuracy and fedelity. We are aiming at reducing cost and time for future engine development by making full use of our numerical simulation to reduce the number of experiments. And also, innovative design methodology for higher performance rocket turbopumps has been investigated by using our numerical simulations.

Ref. URL: https://stage.tksc.jaxa.jp/jedi/simul/index.html

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

In this study, JSS3 has been used because of the following reasons:

(1) To make it possible to perform large-scale numerical simulations with high accuracy and fidelity

(2) To produce a lot of computed results on time within limited short period of time under JAXA's

rocket development

(3) To ensure information security about rocket-related technical information in JAXA's network only

● **Achievements of the Year**

In the fiscal year 2021, the three-dimensional compressible URANS simulation taking into account to simulate flow within turbines. The computed results showed that turbine efficiencies agreed well with experimental results within 4% error. Then, the method is applied to a partial admission turbine, and also showed good agreement with experimental results. Moreover, a new approach to estimate an efficiency of a partial admission turbine is proposed. Fig. 1 demonstrate pressure and density gradient distributions within the partial admission turbine. Fig. 2 shows the flow within the full and partial admission turbine under different operating conditions.

At the same time, a new method to predict a variable stress on turbine blades under resonance conditions is proposed and tested against multiple test cases, and numerical predictions were shown to be in the same order of the experimental results.

The developed numerical simulation approach has been employed in the booster engine LE-9 development of H3 launch vehicle.
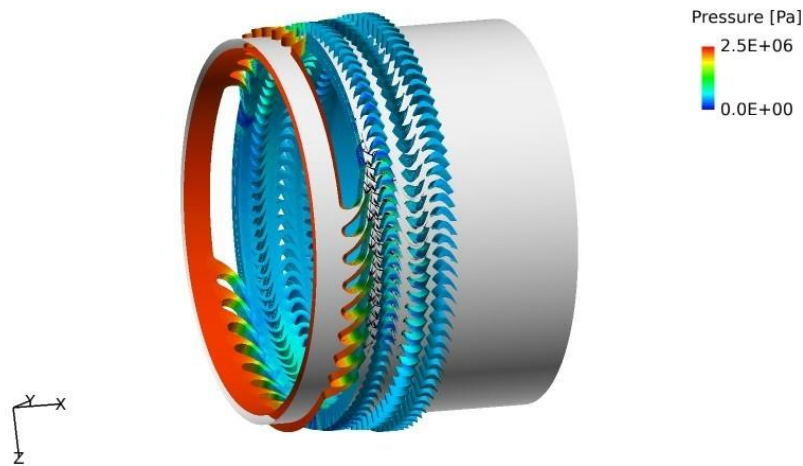

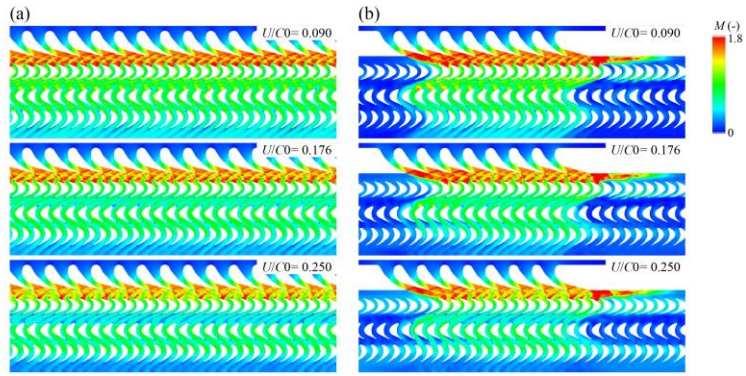Fig. 1: Pressure distribution within the partial admission turbine.

Fig. 2: Distribution of the Mach number at the mid-span plane at different operating conditions(U=C0 = 0:09, 0.176 and 0.250) for a full admission and a partial admission turbine.

● **Publications**

  N/A

● **Usage of JSS**

●   **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	FLAT
Number of Processes	4800 - 20160
Elapsed Time per Case	300 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 3.33

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	78,180,127.04	3.80
TOKI-ST	127,522.22	0.16
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	51,111.69	3.81
TOKI-TST	52.91	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	634.28	0.63
/data and /data2	47,271.32	0.51
/ssd	5,360.47	1.38

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	13.63	0.09

[*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)	2,325.67	1.63

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