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: http://stage.tksc.jaxa.jp/jedi/simul/index.html

Reasons and benefits of using JAXA Supercomputer System

In this study, JSS2 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

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Achievements of the Year

In the fiscal year 2019, the three-dimensional compressible URANS simulation taking into account cryogenic physical properties based on NIST database was applied to liquid rocket hydrogen and oxygen pumps. The computed results showed that the computed pressures in the pumps agreed well with experimental results within 4% error. And also, a supersonic turbine simulation was carried out under the collaboration between DLR and JAXA. Based on the computed results, JAXA has proposed appropriate turbine geometries and measurement positions for a turbine rig test that will be conducted in FY2020.

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

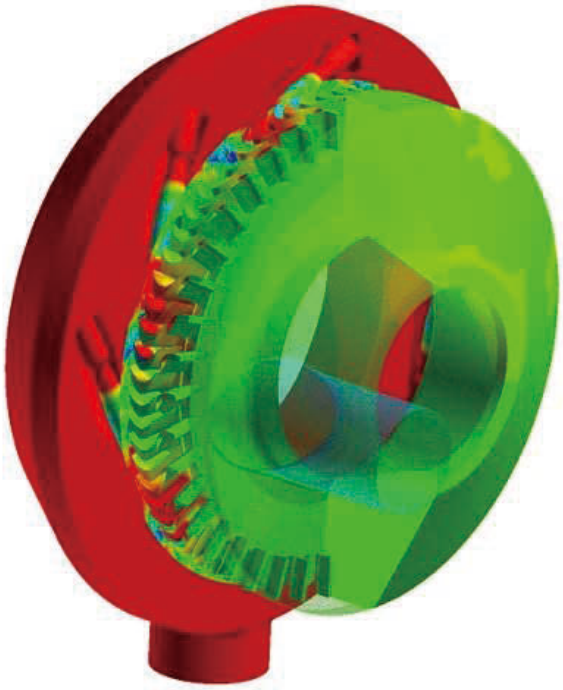

Fig. 1: Pressure distribution of the DLR supersonic turbine

Publications

- Non peer-reviewed papers

(1) Negishi, H., et al., "LUMEN Turbopump -Preliminary CFD Analysis of a Supersonic Turbine with Axisymmetric Nozzles," 32th International Symposium on Space Technology and Science, ISTS 2019-a-08, Fukui, Japan,June. 15-21, 2019.

(2) Negishi, H., et al., "Numerical Study of Tip Clearance Effects in a Centrifugal Pump with Unshrouded Impeller for Liquid Rocket Engines," AIAA Propulsion and Energy Forum, AIAA paper 2019-4433, Indianapolis, IN, August 19-22, 2019.

(3) Negishi, H., et al., "Numerical Study of Tip Clearance Effects in a Centrifugal Pump with Unshrouded Impeller for Liquid Rocket Engines," 81st Turbomachinery Society of Japan, Academic conference, Okayama, Japan, Sep. 2019.

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Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	FLAT
Number of Processes	128 - 16000
Elapsed Time per Case	300 Hour(s)

Resources Used

Fraction of Usage in Total Resources[*1](%): 0.51

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
SORA-MA	4,396,117.93	0.53
SORA-PP	17,332.89	0.11
SORA-LM	1,069.75	0.45
SORA-TPP	847.35	0.05

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	482.46	0.40
/data	31,272.39	0.54
/ltmp	17,115.11	1.45

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	3.90	0.10

[*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.

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