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 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 for using JSS2

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

Achievements of the Year

In fiscal year 2018, we succeded in performing three-dimensional compressible URANS simulation of liquid rocket hydrogen pump considering cryogenic physical properties based on NIST database (See Fig. 1). It was confirmed that computed pressures in the pump agreed well with experimental results within 4% error. The developed numerical simulation approach has been employed in the booster engine LE-9 development of H3 launch vehicle.

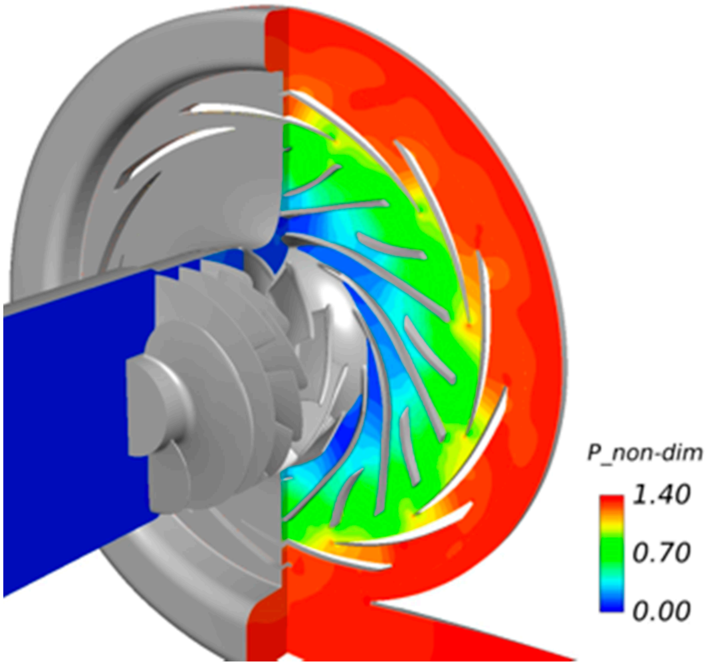

Fig. 1: Computed result of liquid rocket hydrogen pump (pressure distribution)

Publications

- Peer-reviewed papers

(1) Negishi, H., et al., "Investigation on Flow Field Characteristics of a Liquid Rocket Open Impeller Based on Compressible URANS Simulation", Vol. 46, No. 12, Dec. 2018, pp. 705-714.

- Non peer-reviewed papers

(1) Negishi, H., et al., "Computational analysis of flow field characteristics of a liquid rocket unshrouded impeller," 29th IAHR Symposium on Hydraulic Machinery and Systems, IAHR2018-422, Kyoto, Sep. 16-21, 2018.

(2) Negishi, H., et al., "Thermal-flow Field Characteristics of a Liquid Hydrogen Open Impeller (Influence of Flow Coefficient)," 80th Turbomachinery Society of Japan, Academic conference, Oct. 2018.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	FLAT
Number of Processes	128 - 6400
Elapsed Time per Case	300 Hour (s)

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.42

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	3,576,887.13	0.44
SORA-PP	7,545.15	0.06
SORA-LM	1,114.21	0.52
SORA-TPP	19.56	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	495.16	0.51
/data	31,784.03	0.56
/ltmp	16,295.88	1.40

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	2.61	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.