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"Dynamic design method of internal flow systems for rocket turbopumps"

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Abstract

A new dynamic design method of turbopumps is now in the process of developing. In the method, specifications of rotational speed, sizes and masses of pump impellers and turbine are determined first. Then, combination of locations for the components such as impellers, bearings, seals, turbine, and spacers is optimized from the view point of the dynamic characteristics of the rotor assembly focused on the rotor radial vibration, and a several candidates are selected. This is the step1 process of the method. Next, for the several candidates of the combinations, in addition to optimize the rotor diameter and the length of the rotor, optimization of the internal flow system is attempted. This is the step2 process of the method. In the present study, an interactive method to optimize the internal flow system and to verify the feasibility of the axial thrust balancing system is investigated.

As for the static design of the internal flow systems and the axial thrust balancing systems for rocket turbopumps, a lot of studies have been conducted. As for the dynamic design of them, examples are very few. Recently, an analysis model of the dynamic characteristics of the internal flow system including axial thrust balancing system was presented and it was useful to investigate the problem of large amplitude axial vibration in a liquid hydrogen turbopump. In the analysis, one dimensional multi-domain system analysis software AMESim was used. Expanding the analysis model, design feasibility of the combination selected from the view point of radial vibration was evaluated from the view point of the dynamic characteristics of the internal flow system and the axial thrust balancing system.

Configuration of the model investigated is a two-stage centrifugal LH2 turbopump with an inducer driven by a two-stage impulse turbine. First of all, axial thrust balancing

range was confirmed, that is whether or not axial thrust balancing is capable for the configuration selected. Secondly, leakage flow rate of every point in the internal flow system was evaluated. Finally, the stability of the axial thrust balancing system was evaluated. In the case where it is impossible to balance the axial forces; the result is reflected to select another combination of component locations. In the case where it is possible; optimization among the leakage flow rate, the capable range of axial thrust balancing and the stability margin is conducted.

Figure 1 shows the analysis model of the internal flow system and the axial thrust balancing system. The mechanical part of the balance piston and the impellers are modeled as a combination of piston sub-models corresponding to the balance piston and the side-chambers with a mass sub-model corresponding to the rotor assembly. The value of the piston displacement is transferred to the value of the opening areas of the #1 and #2 variable throttling orifices. The leakage fluid passages from the outlet of the main impeller to the inlet of the main impeller through the balance piston were modeled with several sub-models such as variable throttling orifices, pipes, volumes, etc. Perturbation was imposed on the outlet of the second impeller as pressure sinusoidal oscillation or pressure step. In a usual case using the model, the calculation time was less than one minute for one case.

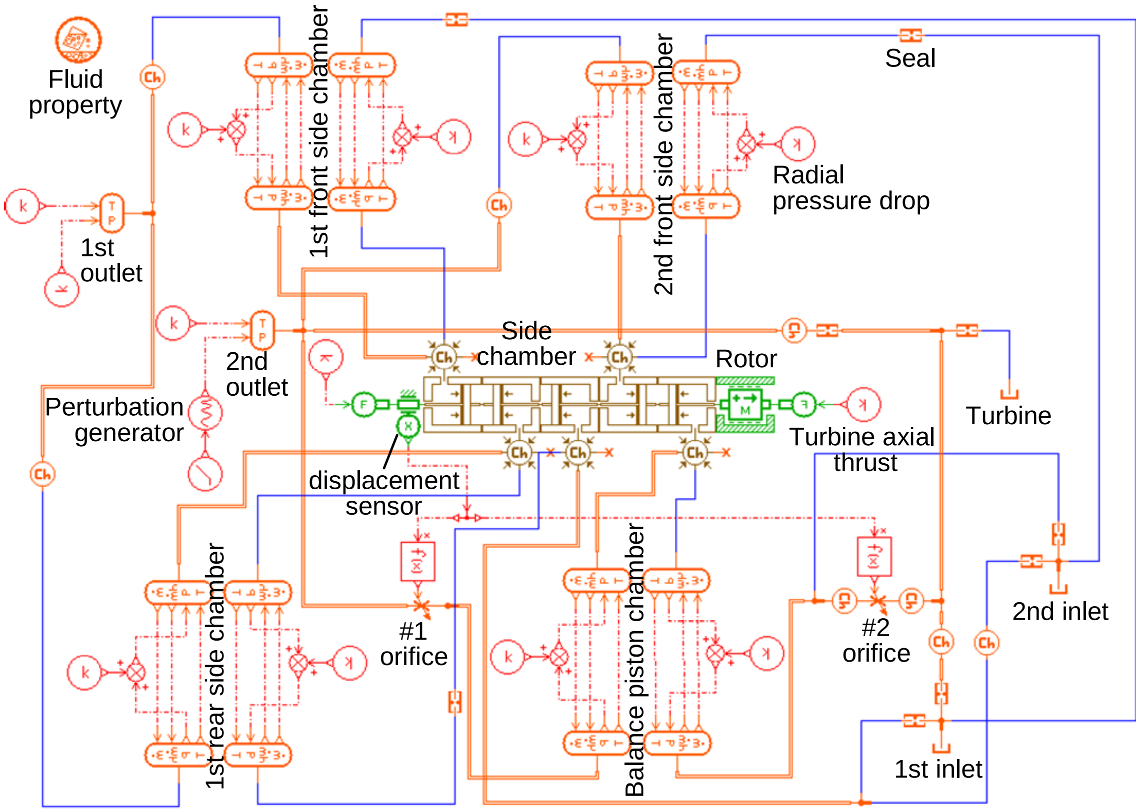

Fig. 1 Analysis model