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Title

Research Activities on Numerical and Experimental Studies of Cavitation Instabilities in the Rocket Engine Turbopump

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Abstract

In recent years, various types of liquid rocket engines have been developed to achieve different types of mission. For the development of innovative transport technologies, modern rocket engines are required to control output power depending on flight situations such as launch and landing, which in turn demands flexible operating range of turbopumps. Turbopumps are, however, subject to undesirable unsteady phenomena particularly under off-design operations, which often cause serious damage of turbopumps leading to a mission failure. Thus, an accurate prediction of unsteady phenomena is of utmost importance for reliable and robust designs of turbopumps in future rocket engines. Therefore, the on-going studies in Research Unit III of JAXA focus on the typical unsteady phenomena observed in turbopumps, cavitation in pumps and flutter in turbines. The present article introduces research overview of numerical simulations as well as experiments of cavitation instabilities observed in an inducer situated upstream of a main centrifugal pump in a turbopump.

The increasing demand for off-design operations of turbopumps may enhance the risk of cavitation instabilities, such as rotating cavitation and cavitation surge. These phenomena are one of the most harmful instabilities generating large pressure fluctuations in the propulsion systems. For example in Japanese launch vehicles, the accident of H-II rocket in 1999 is assumed to be caused by one of the cavitation instabilities in the inducer [1], which gives fatigue damage to the inducer blade in the fuel turbopump of the LE-7 engine. The present article first demonstrates flow simulations of the inducer using URANS/LES to characterize backflow structures linked with cavitation instabilities. The backflow structures are also captured experimentally by PIV from side and upstream views, which is used for the validation of the simulation results. It is worth mentioning that the upstream view of PIV of rocket inducer is captured for the first time to the best of authors` knowledge. Furthermore, the study establishes 1D model for cavitation surge based on characteristic parameters, so-called cavitation compliance and mass flow gain factor. As a result of comparisons with experimental results, the model successfully predicts the frequency the cavitation surge. Then, the 1D model also indicates that dynamic characteristics of cavitation compliance and mass flow gain factor play a key role for the quantitative prediction of cavitation instabilities. The dynamics of cavitation compliance and mass flow gain factor are further investigated to improve the accuracy of the proposed model in the future study.

References

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