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CFD PERFORMANCE PREDICTION OF CRYOGENIC HIGH-SPEED BEARINGS FOR REUSABLE PUMP-FED LIQUID ROCKET ENGINES

Abstract

Reusable rockets are currently the most promising design solution for reducing space transportation costs by saving the efforts of maintenance and increasing the number of launches. The maintenance of turbomachinery requires a large amount of cost. Among these, the bearings of the turbopump are some of the most important components. Several previous studies have suggested that journal bearings can replace ball bearings to extend their lifetime, and hybrid (combined hydrostatic and hydrodynamic) bearings are particularly considered one of the ideal solutions for rocket propulsion systems.

In this research, we conducted numerical analysis to contribute to the development of cryogenic hybrid bearings that enable stable and wide-ranging operations. We performed three-dimensional computational fluid dynamics (3D-CFD) simulations for the tested journal bearings, based on Reynolds-Averaged Navier-Stokes simulations with sub-models accounting for the effects of turbulence and cavitation. Static and dynamic characteristics of high-speed hybrid bearings were investigated focusing on the geometry employing liquid methane of the University of Pisa.

Through a series of simulations changing the shaft speeds and journal eccentricity conditions, we investigated the inlet and outlet pressure ratios and flow rates—important parameters representing the characteristics of journal bearings. Based on the comparison of the results with plain journal bearings, we evaluated the characteristics of test bearings using cryogenic liquid methane with low viscosity.

Furthermore, internal flow in the narrow clearance inside the bearings, based on simulation results, clarified the mechanism of occurring cavitation and its effect on bearing performance. The difference in the pressure distribution and its fluid force with and without consideration of cavitation was also evaluated through the comparison of these results. Cavitating areas, their void fraction, bearing flow characteristics, and dependence on rotational speed and shape of test bearings were especially discussed.