Investigation on Active Axial Thrust Balancing for a Turbopump

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Abstract

A 7 ton class open cycle liquid rocket engine of gas generator type using liquid oxygen and kerosene has been developed and verified through serial ground hot firing tests to be applied as the third stage engine of the space launch vehicle in the KSLV(Korea Space Launch Vehicle)-II program. To increase thrust and specific impulse of the upper stage engine, a 10 ton class closed cycle engine of staged combustion type using the same propellants is going to be developed in the following KSLV-III program. Outlet pressure of turbopump in a staged combustion closed cycle engine is largely increased due to two stage combustion through preburner and main combustor sequentially compared to a gas generator open cycle engine with single stage combustion. The current tubopump for the KSLV-II presents 85 bar head rise in an oxidizer pump and 114 bar head rise in a fuel pump. Since the axial thrust developed by the turbopump is not quite high, a passive thrust balancing is applied so that ball bearings support the axial force. On the other hand, head rise of the next generation turbopump will be increased up to 260 bar in an oxidizer pump and up to 300 bar in a fuel pump. As the axial thrust increases with the higher pump pressure, bearing failure risk also increases due to excessive bearing axial load. Therefore, an active thrust balancing has to be needed to control the axial force. There are two types of active thrust balancing systems. One is a balancing system with one axial control gap and the other is a balancing system with two axial control gaps [1,2]. A balancing system with one axial control gap is priorly considered for the newly developing turbopump due to easiness of design and manufacturing despite lower control capability. The other balancing system with two axial control gaps is also considered as an alternative model since it has superior control capability despite complexity of design and manufacturing in contrast to the balancing system with one axial control gap.

In the present study, two types of active thrust balancing systems with one axial control gap and two axial control gaps respectively are applied for design of the following turbopump through pressure and leakage flow investigation using the analytical method. Axial force of the balancing system is obtained from the converged solution of pressure by matching the pump head rise to the pressure difference summation of total flow passages including balance chamber flow passage and additional secondary flow passage for bearing cooling flow. To decide force equilibrium position and movement range of a rotor system during the balancing, design parameters such as clearance and roughness of annular seal and axial control gap are investigated through the one dimensional flow analysis. A parametric research is performed to extend the axial thrust control span and improve the control sensitivity for various design parameters. Effect on the bearing cooling flow rate is also examined according to the axial thrust balancing design.

References

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