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Heat generation in ball bearing for LOX turbopump

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Ball bearings supporting the main shaft of rocket engine turbopumps which supply cryogenic propellants to the main combustion chamber are critical elements of a rocket vehicle. Inside a turbopump, a portion of propellant is circulated in order to cool ball bearings that are self-lubricating ones using polytetrafluoroethylene as a lubricant. Heat generation of ball bearings rises the coolant temperature which affects its density and mass flow rate. Therefore, it is important to predict the heat generation precisely. In this research, the bearing heat generation in liquid oxygen is measured and compared with one theoretically predicted on a numerical model.

Keywords (from 3 to 5 max): ball bearing, rocket engine turbopump, cryogenic, liquid oxygen

1. Introduction

Cryogenic fluids such as liquid hydrogen, liquid methane and liquid oxygen (LOX) are commonly used for rocket engine propellant. Because the temperature inside cryogenic rocket engine turbopumps is too low to use oil-based lubricants, solid lubricant polytetrafluoroethylene is applied as ones for their bearings although typical lubricants for bearings include oil. Heat generation of ball bearings that include oil is predicted theoretically [1]. However, there is few researches about heat generation of turbopump bearings which are unique because of their environment. Besides the low temperature, the bearings rotate in the propellant. Especially, bearing heat loss in LOX is generated not only from friction but also from fluid churning and drag [2]. In this research, the bearing heat generation in LOX is measured and compared with one theoretically predicted on a numerical model.

2. Experiment and calculation

2.1. Bearing tester

Figure 1 shows cryogenic bearing tester. Electrical motor is used for driving the main shaft. Fluid temperature and pressure are measured. Heat generation is calculated from the differece of enthalpy between upstream and downstream of the bering. Table 1 shows test condition.

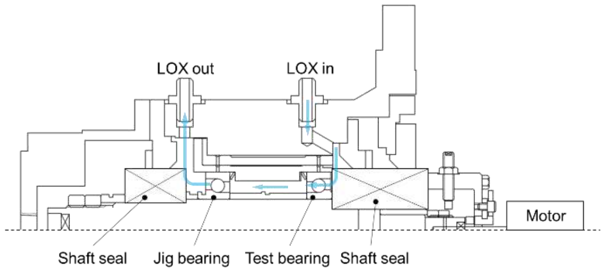

Figure 1 Bearing tester

Table 1 Test condition

Parameter	Test condition
Coolant pressure	1.4 ~ 2.6 MPa
Coolant temperature	108 K
Rotational speed	10600 ~ 19000 rpm
Thrust load	1000 N

2.2. Calculation

Theoretical heat generation is calculated using the theory of bearing motion clarified by Jones [3]. The friction coefficient of contact area is calculated from experimental results of friction tests. The fluid loss is calculated from drag force of spherical and cylindrical bodies.

2.3. Comparison between experimental results and numerical prediction

Figure 2 shows experimental results and numerical prediction. The numerical prediction is approximately equal to the experimental results.

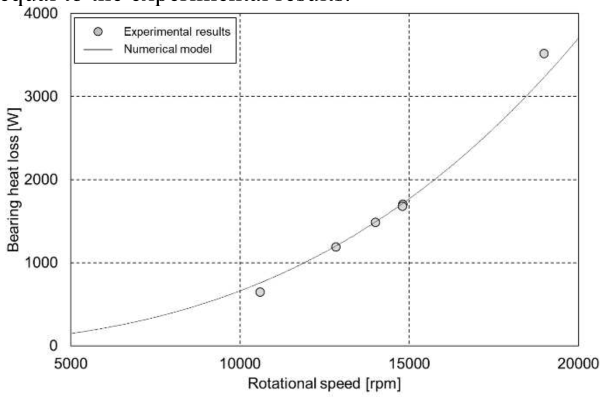

Figure 2 Bearing heat generation as a function of rotational speed

3. Discussion

Using the numerical methods, bearing heat generation in LOX can be predicted approximately. However, there is a difference to the experimental results in higher speed condition. Therefore, accuracy of experimental measurement and numerical prediction should be improved.

4. References

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