Rotordynamic Forces Acting on a Two-Stage Inducer

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Long Abstract

Introduction

Rocket engines are required to provide higher power with lighter weight, and thus the rotational speed of turbopumps of the engines generally become higher than the first critical speed of the rotor. Therefore rocket engine turbopumps sometimes caused self-excited shaft vibration which was generated with the rotordynamic forces induced by a whirling motion of the rotor. Because of the higher power level and higher rotational speed, the rotational stability of rocket engine turbopump is an important factor to increase the reliability.

Yoshida et al. measured rotordynamic forces acting on three-bladed inducer under supersynchronous/synchronous rotating cavitation[1]. The rotating cavitation generate unbalance of the rotordynamic and cause a vibration on the shaft. The shaft vibration varies the clearance between the blade tip and the inner wall and promotes the cavitation because the tip clearance is one of the factor to increase the cavitation. The phenomena is a problem of coupled hydrodynamics with rotordynamics. Pasini et al. measured rotordynamic forces on a four-bladed inducer which are varied with different operational conditions such as flow coefficient, fluid temperature and cavitation number[2]. Both reports show strong nonlinearity of rotordynamic forces against the vibration frequency because of cavitation occurrence.

In this way, the rotordynamic forces on a cavitated inducer caused a shaft vibration and it is difficult to foresee the value because it has a nonlinearity. Establishing a method to measure the rotordynamic forces of a cavitated inducer is a key technology to design the rotor and suppress the shaft vibration. We have developed the equipment which is able to measure the rotordynamic forces. In this report, we present the specification of the equipment and show the measured data of a two-stage inducer as an example.

1.Experimental Apparatus

JAXA has developed a rotordynamic test stand (JARTS) in Kakuda Space Center of JAXA. Figure 1 shows the appearance of the JARTS, vibration exciter and two-stage inducer. The inducer as a specimen is connected vertically to the shaft of the vibration exciter which is connected vertically to an electrical motor, which means that the specimen and the shaft rotate around the vertical axis. We use water as a fluid, and the fluid from a water tank is fed to the inducer, discharged and returned to the tank. During the test operation, we excite a small vibration on the shaft through radial and axial magnetic bearings and measure the displacement of the shaft and the electrical current to control the excitation. The rotordynamic forces is calculated with the measured electrical current data.

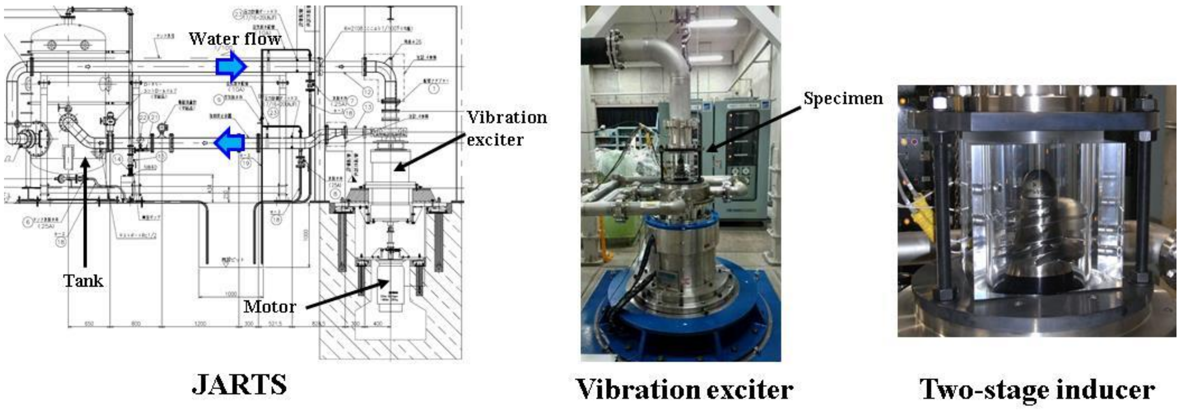

Figure 1. Schematic of JARTS and the test configuration

2.Example of measure data

Figure 2 shows an example of rotordynamic force measured with JARTS. This figure shows the dimensionless value of radial rotordynamic force. ω/Ω is whirling frequency divided by rotation frequency. σ is cavitation number. At σ is 0.013 and 0.042 cavitation has occurred and the radial rotordynamic force were larger than at σ is 0.127. And this figure shows the nonlinearity at ω/Ω is 0.6.

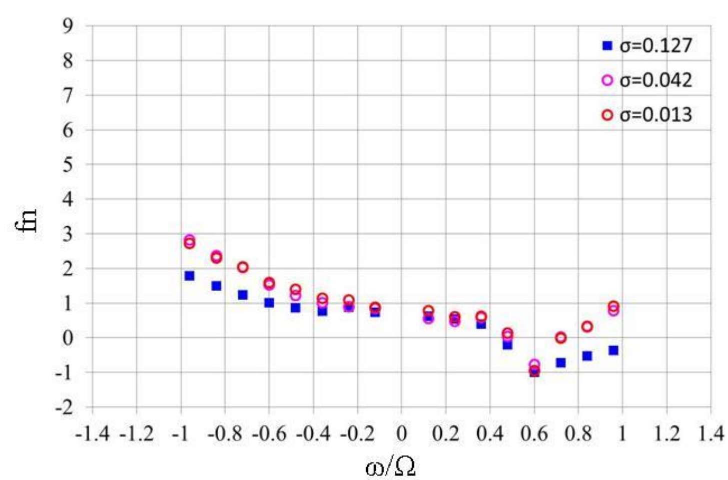

Figure 2. Radial rotordynamic force

References

[1] Yoshida, Y., Eguchi, M., Motomura, T., Uchiumi, M., Kure, H., and Maruta, Y.,2010, “Rotordynamic Forces Acting on Three-Bladed Inducer Under Supersynchronous/Synchronous Rotating Cavitation.” ASME Journal of Fluids Engineering, June 2010, Vol.132

[2] Pasini, A., Torre, L., Cervone, A., and d’Agostino, L., 2010, “Rotordynamic Forces on a Four Bladed Inducer “ 46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit 25-28 July 2010, Nashville, TN