Experimental Identification of Fluid Thin Film dynamic Coefficients for Space Propulsion Turbo Pumps

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Long Abstract

Introduction

Due to a very high power density, the design of turbo pumps, especially for space applications, requires a very good knowledge of the dynamical behavior of the rotor. A great difficulty lies in the influence of the thin fluid film components (like labyrinth seals and fluid bearings) and of impellers. The modelling of the flow in these components might be very complex due to the combined effect of inertia turbulent flow regime and it is then necessary to validate theoretical simulations against experimental results.
Therefore a consortium of French companies (CNES, ASL, EDF R&D, ALSTOM) together with CNRS (French scientific research center) and the University of Poitiers have built a test rig (bench) specially dedicated to the experimental analysis of these fluid components.
This test bench named BALAFRE ("BAnc LAmes Fluides à haut nombre de Reynolds") measures the displacements induced by a dynamic excitations and the resulting fluid film responses. These measurements enable the identification of the dynamic behavior (stiffness, damping and added mass) of fluid bearings, seals or impellers. The paper describes the test rig and some typical results obtained for a centrifugal impeller.

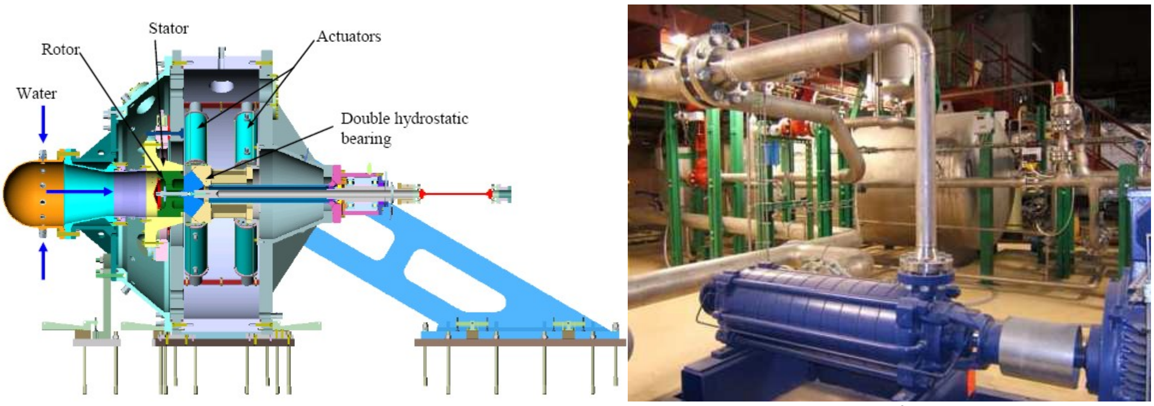
1. Test Rig Presentation

The main objectives of the test rig are to determine the static characteristics (radial load, leakage flow rate) and the dynamic behavior (mass, damping and stiffness coefficients) of tested components operating with thin fluid film flows (impeller, seal, fluid bearing,…) [1][2][3].
The originality of the installation is to perform representative dynamic excitation as met inside an operating turbomachine:
- The dynamic excitations of the component are applied directly by the rotor, contrary to all the existent benches where excitations are applied via the stator,
- Complex displacements of the rotor (translation, precession, pivoting) can be applied for both centered and/or off-centered operating conditions.

Figure 1a presents a cross sectional view of the test rig, where the tested component, here an annular seal (the stator is yellow and the rotor is green), is guided by a double-conical- hydrostatic bearing. This conical bearing is attached to the frame of the test rig via 8 piezo electric actuators, mounted four by four in two planes. The actuators are very stiff and their position is dynamically controlled. This architecture enables to obtain a whole combination of dynamic excitations.
Two warm water (45°C) hydraulic loops are used to feed the test rig:
- a first loop, at 5 MPa and 120 $m^3.h^{-1}$, feeds the tested component and enables operating conditions high Reynolds numbers up to Re # 10^5,
- a second loop, at 15 MPa and 4,8 $m^3.h^{-1}$, feeds the double hydrostatic bearing.

The inlet pressures are controlled and the main parameters (as flowrate, temperatures, forces, etc..)

are constantly supervised. The rated power of the first loop is about 400 kW. Figure 1b shows a part of the hydraulics loops.



a b

Figure 1. Cross sectional view of the test rig a) and view of the hydraulic loops b)

2. Results

Centrifugal impellers as used in space propulsion turbopumps were tested. All the tests were operated with a vaned diffuser and a centered position of the rotor. Steady-state results (displacement, force, pressure, flowrate, temperature, torque) and dynamic forces were recorded for various rotor speeds and water supply pressures.

Dynamic measurements were made for imposed flow rate conditions, i.e. the pressure difference between the supply and the downstream of the volute casing was selected in order to reach a given flow rate at 4000rpm. The excitations were performed for frequencies comprised between 20 Hz and 110Hz with increments of 10Hz. The identified dimensionless stiffness, damping and added mass coefficients are presented.

3. Conclusion

The purpose of this paper is to present the design of this complex and unique test rig (double conical hydrostatic bearing, piezo actuators, hydraulic loops, control and measurement,…) and to present originals experimental results.

References

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