INDUCER AND CENTRIFUGAL PUMP CONTRIBUTIONS TO THE ROTORDYNAMIC FLUID FORCES ACTING ON A SPACE TURBOPUMP

Giovanni Pace, Sitael S.p.A., Pisa, Italy
Dario Valentini, Sitael S.p.A., Pisa, Italy
Angelo Pasini, Sitael S.p.A., Pisa, Italy
Ruzbeh Hadavandi, Sitael S.p.A., Pisa Italy
Luca d'Agostino, University of Pisa, Pisa, Italy

Long Abstract

Introduction

Turbopumps represent critical components for primary liquid propellant rocket engines. Severe limitations are associated with the design of high power density, dynamically stable machines operating with cavitation and capable of achieving the extremely demanding pumping, suction and reliability requirements of modern space flight systems.
Current rocket turbopumps often employ an inducer to avoid unacceptable cavitation levels, improve the suction performance and reduce the propellant tank pressure and weight. The main role of inducers consists in pressurizing the flow sufficiently for the following centrifugal stage(s) to operate satisfactorily.
Rotordynamic forces, together with flow instabilities, are one of the most recognized and dangerous sources of vibrations in turbomachines and arise due to an eccentric motion of the pump. These forces can affect all the components of the machine, including the bearings, the seals and the impeller itself. The presence of cavitation can heavily influence the dynamic behavior of pumps by reducing the added mass and so the critical speed. Cavitation can affect rotordynamic forces by changing direction and intensity thus enforcing/decreasing the pump whirling motion.
The rotordynamic forces acting on centrifugal pumps have been extensively measured and investigated in the past by many researchers, even if the influence of cavitation has not been widely investigated and few experimental results exist about this topic.
The rotordynamic forces acting on axial inducers, especially when unshrouded (which is the case of virtually all the inducers used for space applications), are still not well studied and understood at the present day, even if some studies have been performed at Caltech in the 80's and recently at ALTA.

1. Methods

The rotordynamic configuration of the test facility at Sitael is specifically intended for the analysis of steady and unsteady fluid forces and moments acting on the impeller as a consequence of its whirl motion under cavitating or fully-wetted flow conditions.
An extensive experimental activity has been conducted on a six-bladed centrifugal pump, a three bladed axial inducer and a combined configuration with the inducer mounted upstream of the centrifugal pump. The test campaign aimed at characterizing the unsteady fluid forces and moments acting on the impellers as a consequence of their whirl motion under cavitating/noncavitating conditions.
The paper will present the most significant results obtained on the combined configuration by underlining the influence of each items (the centrifugal pump and the inducer) on the behavior of the rotordynamic forces acting on the whole turbopump.

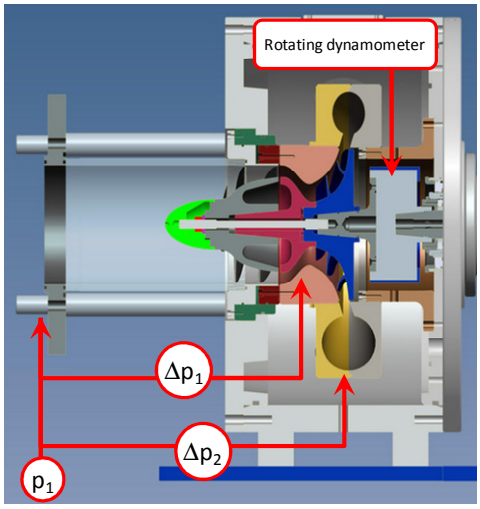

Figure 1. Main transducers arrangement in the pump+inducer configuration.

References

[1] Pasini A., Torre L., Cervone A., and d'Agostino L., 2010, "Rotordynamic Forces on a Four Bladed Inducer," in 46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Nashville, USA.

[2] Torre L., Pasini A., Cervone A., and d'Agostino L., 2011, "Continuous Spectrum of the Rotordynamic Forces on a Four Bladed Inducer," in ASME-JSME-KSME Joint Fluids Engineering Conference, Hamamatsu, Shizuoka, Japan.

[3] Torre L., Pasini A., Cervone A., Pecorari L., and Milani A., 2010, "Rotordynamic Forces on a Three Bladed Inducer," in Space Propulsion Conference, San Sebastian, Spain.

[4] Pace G., Pasini A., Torre L., Valentini D., and d'Agostino L., 2012, "The Cavitating Pump Rotordynamic Test Facility at ALTA S.p.A.: Upgraded Capabilities of a Unique Test Rig," in Space Propulsion Conference, Bordeaux,France.

[5] Torre L., Pasini A., Cervone A., and d'Agostino L., 2011, "Experimental Characterization of the Rotordynamic Forces on Space Rocket Axial Inducers", ASME J. Fluids Eng., 133(10).

[6] Pasini A., Torre L., Cervone A., and d'Agostino L., 2011, "Continuous Spectrum of the Rotordynamic Forces on a Four Bladed Inducer", ASME J. Fluids Eng., 133(12).