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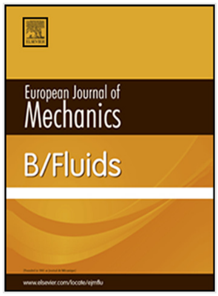

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Fluid-Induced Rotordynamic Forces on a Whirling Centrifugal Pump

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Abstract

The experimental characterization of the rotordynamic fluid forces acting on a whirling centrifugal impeller have been investigated at different flow rates and cavitating conditions. The recently developed method for continuously measuring the rotordynamic forces at variable whirl ratios has been readapted and successfully applied for measuring the same forces at constant whirl ratio but variable cavitation number. The flowrate has a major influence on the stability of the rotordynamic forces at positive whirl ratios where a threshold flowrate separates the stable zone from the unstable. At negative whirl ratios, the normal force is typically unstable independently on the flow rate. Cavitation has always a destabilizing effect at positive whirl ratio while it can stabilize the rotordynamic forces at negative whirl ratio.

Keywords

Rotordynamic — Radial Impeller — Cavitation — Performance

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1. INTRODUCTION

Chemical rocket propulsion and its derivative concepts will continue to play a central role in future STSs (Space Transportation Systems), being the only viable technology capable of generating the relatively high levels of thrusts necessary for launch and most primary propulsion purposes in a large number of space missions.

Propellant feed turbopumps are an essential component of all primary propulsion concepts powered by Liquid Propellant Rocket Engines (LPREs). Rotordynamic forces, together with the flow instabilities possibly triggered by the occurrence of cavitation, are one of the universally recognized and most dangerous sources of vibrations in turbomachines [1,2,3,4]. These forces can affect the impeller itself, and all the components of the machine [5]. The rotordynamic configuration of the Cavitating Pump Rotordynamic Test Facility (CPRTF, see [6] for further information) at SITAEL (formerly ALTA) 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, with special emphasis on the onset and development of lateral rotordynamic instabilities. Even if steady and rotordynamic forces acting on centrifugal pump impellers have already been extensively studied (see for example [7,8]), the influence of cavitation on rotordynamic fluid forces has not yet been investigated in great detail. Available experimental data mainly come from the work carried out at the California Institute of Technology [1,2,3,9,10], and later at ALTA by the Chemical Propulsion Team [11,12,13,14].

Recently, an experimental campaign has been carried out at ALTA under ESA funding with the purpose of investigating the influence of the operational conditions (flow rate, suction pressure) and liquid temperature (inertial/thermal cavitation) on the rotordynamic forces acting on a six-bladed centrifugal impeller. In the experiments the impeller is subject to a whirl motion of given constant eccentricity and angular velocity. A special procedure, recently developed and validated at ALTA [13], has been used to measure the continuous spectrum of rotordynamic forces as functions of the whirl-to-rotational speed ratio for the first time on a centrifugal impeller. This procedure proved to be very effective in providing accurate and frequency-resolved information on the dependence of rotordynamic impeller forces on the whirl ratio and the operational conditions of the machine. In particular, the maxima and minima of such forces can be clearly identified, together with the general trend of their spectral behavior. Moreover the new procedure easily allows for the simultaneous evaluation of the rotordynamic forces along with the non-cavitating and suction performance of the test machine.

2. EXPERIMENTAL APPARATUS

The experimental activity reported in the present paper has been carried out in SITAEL's Cavitating Pump Rotordynamic Test Facility (CPRTF), illustrated in Fig. 1 and specifically designed for characterizing the performance of cavitating and/or non-cavitating turbopumps in a wide variety of alternative configurations: axial, radial or mixed flow, with or without an inducer [6]. The facility uses water as working fluid at temperatures up to 90 °C and is