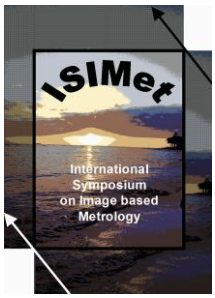
Experimental Study of the Unsteady Flow Mechanisms Causing Performance Degradation and Originating Machine Instabilities on a Multiphase Pump by Means of Flow Visualization



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Long Abstract

Introduction

The flow inside of turbomachines rotating channels, when operating away from the design point, is intrinsically unsteady; two-phase flow and part-load operation further complicate the analysis, introducing additional challenges. Secondary flows, additional losses and increased noise and vibration levels arise. These operating conditions not only affect the machine efficiency, but are also accompanied by marked flow instabilities, comprising characteristic phenomena as recirculation, eddy flows within the impeller and casing and the wear rings and the typical surging and rotating stall conditions.

Despite some specific research studies have succeeded in providing an overall description of the machine behavior at instabilities, as the estimate of performance degradation [1-6] and the prediction of the surging onset [7], the results remain highly dependent on the specific machine design and operating conditions. Furthermore, the phenomena involved present an intermittent, unpredictable and three-dimensional character, which cannot be effectively accounted for in analytical modelling and represent a real challenge for numerical codes, as they would require excessive computational efforts for transient simulations and extremely fine grid spacing, to model the strong local gradients for boundary layers and flow-bubble interaction.

The flow regimes vary from a homogeneous distribution of fine bubbles, evenly dispersed and carried away by the main flow, to more complex flow patterns, especially when the phases separate or the bubbles coalesce forming an unsteady gas pocket which adheres to a wide portion of the channel wall.

Investigations, Tools and Results

A multiphase pump laboratory [8], recently installed at the Norwegian University of Science and Technology, allows a complete optical access to the pump channels and fine adjustments in the inlet configuration and the tip clearance gap; the air can be injected from different locations producing transient regimes too.

A high speed camera provides an interesting insight into the transient flow phenomena.

The main goal of the investigation has been set to the experimental description of the flow regimes in the different performance map zones; afterwards, focus has been given to the recognition of the originating unsteady flow mechanisms responsible for flow-field modifications, which affect the machine stability. These comprise:

- Irregular backflow and swirl at the inlet section
- Gas accumulation zones and contribution of the tip leakage to mixing
- Flow pattern shift to phase segregation
- Origin of pump blockage
- Flow and machine parameters response to a variation in the inlet flow

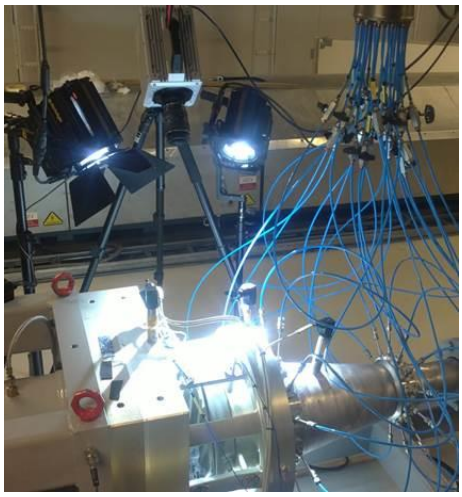

Figure 1. Flow Visualization Setup

Tests are performed at various operating conditions – rotational speed, mixture composition and impeller tip clearance.
The study is completed with the time and frequency domain analysis of the pressure pulsations at surging and during specific transient events.
Further steps of the project include the evaluation of advanced visualization techniques, which, complemented by image based metrology, allow a more detailed reconstruction of the flow field, providing useful information on the individual phase velocity. Once the validity of these techniques is assessed, the numerical simulations predictions will be validated experimentally.

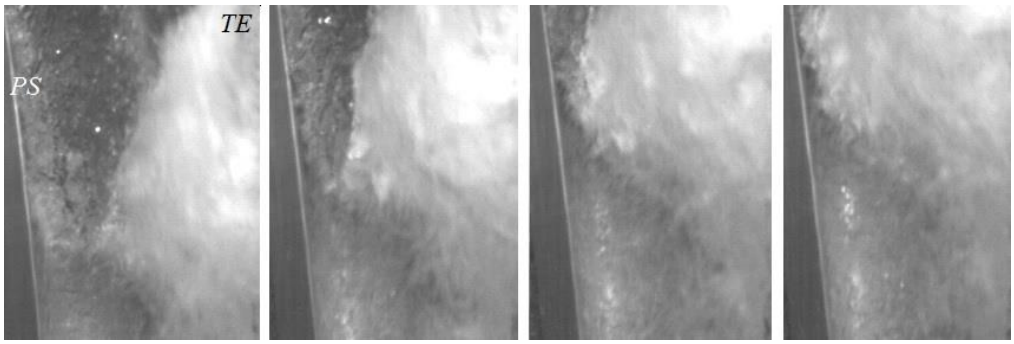

Figure 2. Gas Pocket Unsteady Evolution

References

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