A Data Acquisition System to Detect Bubble Collapse Time and Pressure Losses in Water Cavitation

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ABSTRACT

This paper presents a data acquisition system oriented to detect bubble collapse time and pressure losses in water cavitation in an internal orifice. An experimental campaign on a cavitating flow of water through an orifice has been performed to analyze the flow behavior at different pressures and temperatures. The experiments were based on visual observations and pressure fluctuations frequency analysis. Comparing the visual observations and the spectral analysis of the pressure signals, it is evident that the behavior of the different cavitating flows can be correlated to the frequency spectrum of the upstream, downstream and differential pressure fluctuations. The further reduction of the cavitation number and the consequent increase in the width of the cavitation area are related to a corresponding significant increase of the amplitude of typical frequency components. The spectrogram analysis of the pressure signals leads to the evaluation of the bubble collapse time, also compared with the numerical results calculated by the Rayleigh-Plesset equation.

Keywords: Bubble Collapse, Cavitation, Orifice, Pressure Losses, Spectral Analysis, Visualizations

INTRODUCTION

The cavitation phenomenon constitutes a research field of increasing interest over the last years, as attested by several works (Abdel-Maksoud et al., in press; Arndt et al., 1999; Brennen, 1995; Payri et al., 2009; Schneider et al., 2007; Suh & Lee, 2008; Tseng & Shyy, 2010; Vortmann et al., 2003) dealing with it in the attempt to underline several aspects, problems and characteristics. This phenomenon interests a wide range of machines, from internal combustion engines to turbines and pumps of all sizes. It affects negatively the performance of hydraulic machines and may cause material erosion.

In hydraulic machines, cavitation may occur along stationary parts and along moving...
blades. Liquid fuel and oxidizer turbo-pumps for rocket engines are usually operated under cavitating condition with quite high rotational speed to attain high-pressure performance with their minimum size and weight. Under such conditions, inducers easily fall into unstable operations with severe instabilities such as cavitating surge and rotating cavitation.

Cavitation occurs when, due to a decrease in local pressure up to the vapor pressure, cavities filled with water vapor are formed; once the vapor bubbles reach higher pressure regions on their paths they collapse by an implosion. When cavitation bubbles collapse near the surface of a solid in contact with the liquid, tiny pits or craters damage the solid surface. A problem related to the transport and manipulation of multiphase fluids, as cavitating flow, concerns the individuation of the different characteristic flow patterns and its strong influence on important operation parameters of the machinery.

Over the past few years many researchers have made an effort to carry out data acquisition systems to observe, to display and monitoring the cavitating flow in order to understand its behavior, formation mechanisms of cloud cavitation, and stability of cavitation characteristics. Although prediction based on phenomenological models is fairly well developed, on-line monitoring of cavitating flow patterns is still a limiting technological problem. Flow visualization is an important tool in fluid dynamics research and it has been used extensively in the different fields as engineering, physics, medical science, etc. Visual observations and photographic recordings have been performed in many practical situations as experimental means to provide a “measure” of the cavitation phenomenon. Cavitation structures behave stochastically both in time and space, with a very rapid change within microseconds. In (Ezddin et al., 2008) a visualization of a highly submerged cavitating water jet was done by high-speed camera photography in order to study and understand the jet structure and the behavior of cloud cavitation within time and space. Periodical shedding and discharging of cavitation clouds have been analyzed and the corresponding frequency was determined by cloud shape analysis. Also Soyama et al. (1995) attempted to clarify the jet structure and the behavior of severely erosive cavitation clouds around a high-speed submerged water jet, using a high-speed movie camera with a framing rate of ten thousand frames.

In the past studies (He & Ruiz, 1995; Ramamurthi & Nandakumar, 1999; Tullis & Govindarajan, 1973) there is a great deal of interest for cavitation in orifice. The internal flow through an injection nozzle is a very important aspect of spray formation and atomization generated by the nozzle, influencing the nozzle’s combustion efficiency and the formation of pollutants. A better understanding of the complex nature of flow intra nozzle is necessary for predicting spray development. The internal flow process is very complex. Nurick (1976) studied cavitation characteristics for circular and rectangular orifices. Sharp-edge orifices were incorporated into unlike-impinging-doublet injector elements. The spray mixing uniformity was determined at cavitating and non-cavitating conditions. Cavitation was shown to result in a substantial reduction in mixing uniformity for circular orifice elements. Over an identical range in experimental conditions, the rectangular orifice element did not experience lowered mixing uniformity. The orifice cavitation and mixing results should find use in a wide range of applications. Recent experimental studies (Tamaki et al., 1998, 2001) show that the occurrence of cavitation inside the nozzle makes a substantial contribution to the breakup of the exiting liquid jet. They present an experimental study of the flow in a relatively large-scale channel, which was used to reproduce the flow pattern in a square-edged diesel injector orifice by dynamic similarity. A fixed cavity was formed at the corner of the orifice inlet by reducing the absolute pressure in the flow. Both cavitating and non-cavitating flows were measured by using a laser Doppler velocimeter. Significant changes in mean flow and turbulence have been found in the presence of the cavity. Turbulence in the cavitating flow is higher and decays more slowly than that in
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