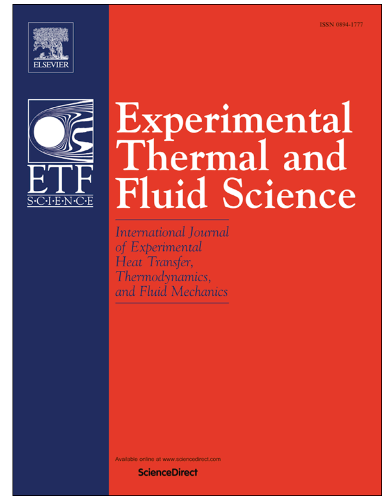

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Observing the thermodynamic effects in cavitating flow by IR thermography

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Abstract
When dealing with liquid flows, where operating temperature gets close to the liquid critical temperature, cavitation cannot be assumed as an isothermal phenomenon. Due to the relatively high density of vapor, the thermodynamic effect (decrease of temperature in the bulk liquid due to latent heat flow) becomes considerable and should not be neglected. For applications like pumping cryogenic fuel and oxidizer in liquid propulsion space launchers, consideration of the thermodynamic effect is essential - consequently the physical understanding of the phenomenon and its direct experimental observation has a great value.
This study presents temperature measurements in a cavitating flow on a simple convergent-divergent constriction by infrared (IR) thermography. Developed cavitating flow of hot water (~100°C) was evaluated by high-speed IR thermography and compared with conventional high-speed visualization, at different operating conditions with the velocity range at the nozzle throat between 9.6 and 20.6 m/s and inlet pressure range between 143 and 263 kPa.
Temperature depression near the nozzle throat - near the leading edge of cavitation was measured in a range up to ΔT=0.5 K. This confirms the presence of the thermodynamic effects by cavitation phenomenon and it is in agreement with its theory. In the study, average temperature fields, fields of temperature standard deviation and time-resolved temperatures, are presented and discussed. In addition, statistical analysis between temperature drop and cavitation flow characteristics is shown.

Key words: thermodynamic effect, cavitation, temperature measurements, thermography, convergent-divergent nozzle

1 Introduction

Cavitation, a physical phenomenon driven by local pressure drop in a liquid, is characterized by growth and collapse of small vapor-gas bubbles. In most cases, when for example we are dealing with cold water flow, one can assume the cavitation being an isothermal process. But it is known, that the cavity growth is driven mainly by the evaporation process, where the supplied latent heat from cavity surrounding causes a small temperature drop of the liquid, which results in a local drop of a vapor pressure. Further development of the bubble is now weakened or delayed, thus greater pressure drop is needed to maintain the cavity growth. This is known as the thermodynamic effect or thermal delay phenomenon and has a direct influence on the bubble dynamics. The effect becomes important when the operating temperature is close to the end point of a phase equilibrium curve (critical point) of the liquid – for example in cryogenic liquid flow. The latter is of an extreme interest to the scientists and engineers due to its usage in liquid propulsion space launch vehicles – there is a well-known example of space launch failure of Japanese H-II rocket due to the cavitation instability in the liquid hydrogen