Cavitation Erosion in Water at Elevated Temperature

Matevž Dular, Faculty of Mechanical Engineering, University of Ljubljana, Slovenia
Roman Šturm, Faculty of Mechanical Engineering, University of Ljubljana, Slovenia
Marko Hočevar, Faculty of Mechanical Engineering, University of Ljubljana, Slovenia

Long Abstract

Introduction

Optimal operation of turbopumps is crucial for all liquid fuel rocket engines. To reduce weight, these pumps often operate at critical conditions, where dynamic instability and cavitation are unavoidable. In cryogenic engines, the fuel and oxidizer used are liquid usually hydrogen and liquid oxygen at very low temperatures (about 14 and 90 K, respectively). Usually we treat cavitation as an isothermal phenomenon, but this assumption is not valid for such propellants: flows are characterized by a substantial cooling during the vaporization process due to cavitation [1]. This phenomenon delays the further development of cavitation, so it plays a moderation role in the cavitation increase. The numerical prediction of the thermal effect is therefore a major industrial issue. Similarly a more in-deep understanding of cavitation erosion is extremely important for future reusable components, designed in order to withstand longer lifetimes without suffering potentially dangerous damages.
Many studies were already performed to investigate cavitation erosion associated with thermodynamic effects, yet, due to the complexity of the measurements, in most experiments ultrasonic devices are used to generate cavitation [2].
In the proposed contribution we show experiments, where cavitation was generated hydrodynamically. Cavitation erosion on soft metal specimens in waters with temperatures of up to 120°C was studied.

1. Methods

Erosion was studied in radial flow geometry (Fig. 1). The test section was made out of stainless steel with one inlet and four outlets. In the back wall two specimens could be mounted simultaneously – usually only one polished aluminum specimen and a transparent window for cavitation monitoring were used.

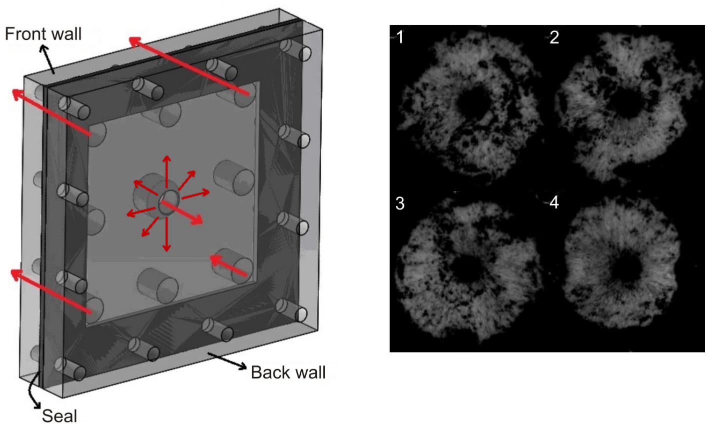

Figure 1: Test section (left) with a typical cavitation structures (right).

The section was mounted into a cavitation tunnel with a closed loop circle what enables to vary both the flow rate and the system pressure and in addition a precise setting of the operating temperature.

This way a wide range of operating points can be achieved.

The idea was to obtain sufficient damage in a relatively short period of time (in about 1 to 2 hours). An extremely aggressive type of cavitation was achieved at 20 m/s at the outlet and at 4.5 bar upstream pressure (at 20 °C) – $\sigma = 2.23$. The cavitation number and the flow velocity were preserved for all tests (only the upstream pressure was adjusted for other operating temperatures).

Damage evaluation was performed using a macro objective Tukina 70-300mm and a digital camera Nikon D3100. Resolution of approximately 5μm per pixel could be obtained. The evaluation followed an established pit-count procedure where the pits are recognized as the darker regions in an image, while the brighter area is assumed to be undamaged surface. The pit-count method gives a distribution of the number and the area of the pits and consequently, the distribution of the magnitude of cavitation erosion on the surface [3].

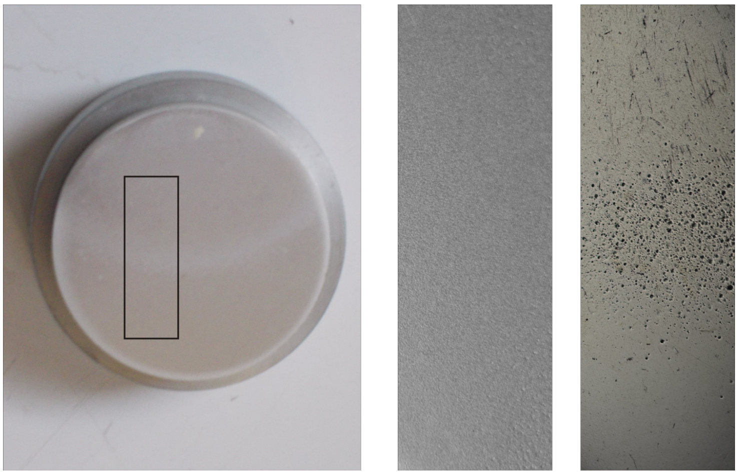

Figure 2: A damaged specimen after 30 minutes of exposure to cavitation.

In the results section we show comparison of erosion patterns, magnitudes and topology of cavitation structures for cases of thermosensible fluid flow. These will reveal new insights of how thermodynamic effects influence the erosion process.
A development of cavitation erosion model for thermosensible fluids is shown. The cavitation erosion model bases on the physical description of different phenomena (cavitation cloud implosion, pressure wave emission and its attenuation, micro-jet formation, splashing, spherical micro bubble collapse, pit formation an finally mass loss), which are involved in the process of damage formation.

References

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[3] M. Petkovšek and M. Dular. Simultaneous observation of cavitation structures and cavitation erosion, *Wear* **300** (1/2) (2013) 55-64.