Modeling of cavitation phenomenon in spacecraft turbopumps

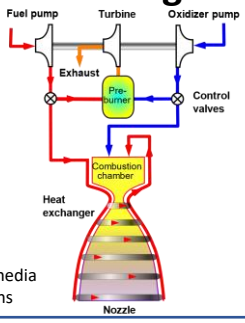
Joris Cazé, Fabien Petitpas, Éric Daniel, Matthieu Queguineur, Sébastien Le Martelot

LABORATOIRE AIX MARSEILLE UNIVERSITÉ CNRS

JC² October, 6, 7, 8 2021

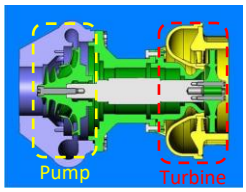
Overview

Rocket engine



© Wikimedia Commons

Turbopump

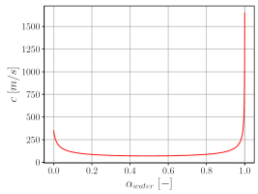


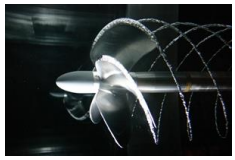
© Solutions engineering

Specific $\dot{m}$ & Δp for combustion chamber

Cavitation

- Mechanical instabilities
- Mass flow reduction





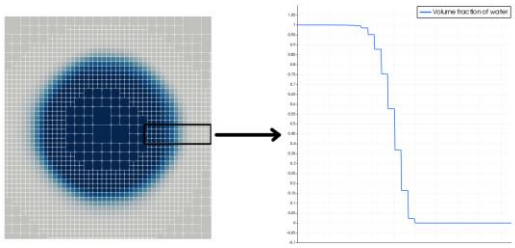
Boat propeller © Héliciel

Numerical simulation

- Multiphase models
- Compressible flows
- Phase change

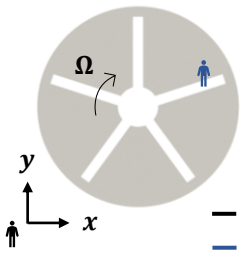
Modelling

Diffused interfaces method and waves interaction modelling [1]



+ Blades movement

Moving Reference Frame method [2]



Inertial frame

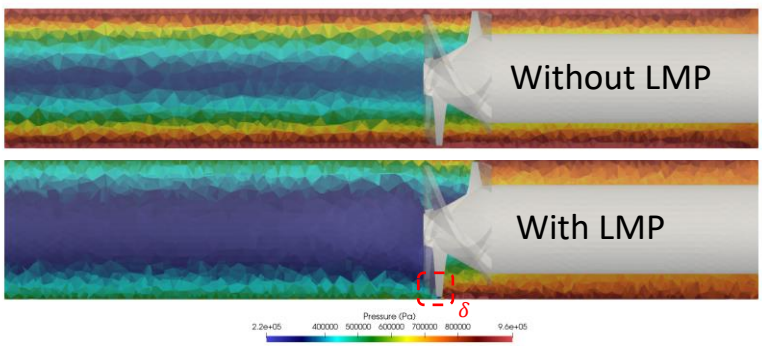
Rotational frame

+ Extra physics

- Low-Mach preconditioning for liquid regions [3]
- Phase change for cavitation [4]
- Viscous effects in the gap region $Re_\delta \sim 10^3$

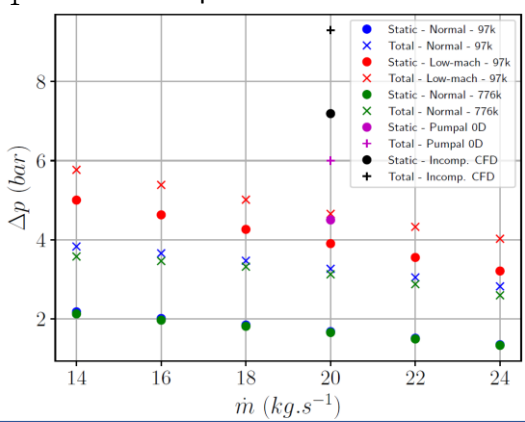
Results

Impact of the low-Mach preconditioning (LMP) for $\dot{m} = 20\ kg.s^{-1}$



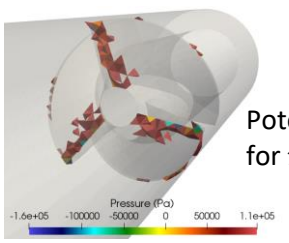
Computed with ECOGEN [5]

Pump characteristic curve



Conclusions

- ✓ Pump characteristic curve for single-phase flow
- ✓ First estimation of cavitation regions



Potential cavitation regions for $\dot{m} = 14\ kg.s^{-1}$

Work in progress → cavitation

- Study of volume fraction expansion
- Study of phase change impact

References

[1] Cazé, J. et al. (2021), *Modelling interactions between waves in diffused interfaces method for multiphase flows,* in preparation.

[2] Cazé, J. et al. (2022), *Simulation of multiphase flows in rotative reference frame,* in preparation.

[3] Le Martelot, S. et al. (2013), *Liquid and liquid–gas flows at all speeds*, JCP.

[4] Petitpas, F. et al. (2009), *Diffuse interface model for high speed cavitating underwater systems*, IJMF.

[5] Schmidmayer, K. et al. (2020), *ECOGEN: An open-source tool for multiphase, compressible, multiphysics flows*, CPC.