Summary of D4.2: A New Erosion Risk Assessment Procedure for Engineering Applications

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Maritime industry has an increasing demand for CFD models that can predict the risk of cavitation erosion for ship propellers and rudders. Problems with cavitation erosion are typically encountered when the hydrodynamic efficiency of propellers and rudders is aimed to be increased. For this reason, the assessment of cavitation erosion risk should ideally be incorporated in the early design optimization process to achieve an appropriate compromise in this trade-off. In order to assess the risk of cavitation erosion reliably, the capabilities of cavitating flow solvers need to be taken into account in the design of erosion risk prediction tools. The modeling approach introduced in this study is motivated by the finding that flow solvers typically used in maritime industrial practice can correctly resolve the kinematics of cavitating flows as far as cavity collapse time and the frequency of periodic cavitating flows are concerned. Since these flow solvers are mostly based on originally incompressible modeling approaches, however, they fail to correctly predict the peak amplitude of local surface pressure loads resulting from violent cavity collapses.

For this reason, the modeling approach introduced in this study is strongly related to the kinematic properties of cavitating flows. Recently, Leclercq et al (2017) have developed a cavitation intensity model describing the local surface impact power from the solid angle projection of released potential cavity energy on triangular surface elements. In this study, a fully continuous form of the model is derived, providing the surface specific impact power on a point location. The modeling approach is energy conservative with respect to the potential cavity energy as defined by Hammitt (1963). The aggressiveness of the cavitating flow is then assessed from filter functions providing a weighted average of the local impact power signal. With the increase of a model parameter, the extreme value of the time signal is given more weight, but the weighted average can never be larger than this extreme value. Thus, the new aggressiveness indicators provide a more realistic and quantitative measure of the flow aggressiveness than already existing indicators. The erosion risk assessment procedure is implemented as a runtime post-processing tool in the open source CFD package OpenFOAM. The technique is verified by comparing the accumulated surface energy resulting from the close wall collapse of idealized cavities against analytical predictions. Furthermore, the effect of cavity shape and orientation relative to the impacted surface is elaborated on. It is found that the ranking of the cavity types in order of their aggressiveness can be different depending on whether the focusing of energy or the focusing of impact power is employed as an aggressiveness criterion. The new indicators are further employed to assess the aggressiveness of a cavitating flow around a NACA0015 hydrofoil. The results are compared to damage patterns obtained experimentally by Van Rijsbergen et al (2012) and to numerical erosion risk results by Li et al (2014) for the same test configuration.

Ongoing research concerns the flow aggressiveness of a cavitating flow around a marine propeller in artificial wake inflow, using RaNS equations as the flow modelling approach. As part of the cooperation with the CaFE project partner Wärtsilä, the erosion risk assessment procedure is aimed to be implemented in the commercial CFD-package STAR-CCM+. It is shown that the approach requires parallel CPU's to communicate in a way that is typically not supported by user function or user coding environments of standard commercial CFD software, thereby imposing a practical limitation when commercial software without source code access is used. The solution of the CPU communication problem implemented in OpenFOAM is presented.