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Numerical Modelling of Cavitation Using Energy Approach

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Extended Abstract

Cavitation in positive displacement pump is life and performance limiting phenomenon. Cavitation erosion is a set of complex multistage event which involves formation of vapour bubbles due to low pressure generation, bubble travel/ growth, collapse and material erosion. The difficulty in obtaining experimental data under the aforementioned conditions has boosted the increasing demand for developing a validated computational fluid dynamics models. An increasing number of numerical models have appeared in the literature, which allows modelling the formation and development of cavitation inside the pumps. Most models are based on the assumption that cavitation is initiated by the presence of cavitation nuclei which grow to become bubbles and then to form the complex cavitation structures which can be observed experimentally. Cavitation bubble generation and collapse rates are functions of the instantaneous local static pressure which is modeled through cavitation model based on Rayleigh – Plesset equation, describing growth of single vapor bubble in a liquid. Structural damage of pump components due to cavitation demands detailed modelling mechanism leading to bubble growth/collapse.

In current effort, CFD methodology has been established for prediction of cavitation. During the first stage of the effort, a simple case of flow through a venturi is simulated. The resulting flow field along with the cavitation volume closely correlated with experimental findings in literature (Barre et al., 2009). In the next stage, effect of various multiphase models such as mixture, Euler and VoF (Volume of Fluid) and 'Schnerr and Sauer' and Singhal cavitation models on cavitation, are studied. Effect of dissolved air is also incorporated in the simulation and the effect of the same is observed. Implementing these learnings in the last stage of the study, a full three dimensional transient flow simulation of a piston pump is performed using a dynamic mesh technique. k-ε turbulence model was applied to capture turbulence effects. Due to complex pump dynamics and multi-phase flow, enormous numerical instability and convergence issues needed to be handled. Low pressure region is observed in numerical simulation leading to generation of vapour bubbles. The transport of these bubbles to high pressure region is seen to cause the bubble collapse. Cavitation material damage prediction needs additional numerical treatment. In the current effort transient flow field information such as pressure and vapour bubble volume is extracted from multiphase flow simulation. This pressure and volume is used to calculate the vapour collapse work. The cumulative work gives an estimate of bubble collapse energy release which leads to material damage.

The proposed methodology is applied and verified on three different designs of piston pump. Erosion location observed from experiment shows a close correlation with the CFD predicted bubble collapse location. Energy calculated using CFD flow parameters is compared with extent of material damage. It is observed that the energy calculations show good correlation with the extent of erosion damage. Thus current methodology can be used to qualitatively model the cavitation phenomenon in pumps and rank various designs in the order of this collapse energy and hence the susceptibility to damage. Further experimental investigation needs to be carried out to extend the methodology to calculate the energy threshold at which material damage would get initiates.

References

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