Mechanical Engineering Master's Defense

Analysis of Cavitation-Induced Pressure Loads on Compliant Polymer Coatings

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abstract

Cavitation erosion is a significant cause of wear in marine components, such as impeller, propeller, vessel etc.. While the erosion process has been widely studied on metals, the effect of cavitation on polymers is not well-understood. As the stress response in metals differs greatly from that of polymers, e.g. rate and temperature effects are far more important, damage and wear mechanisms in polymers are not the same as for metals. In this work, two possible material failure mechanisms are explored: 1) heat-driven failure from viscous dissipation, and 2) void nucleation caused by tensile stresses due to wave reflections at the interfaces between coating and substrate, and coating and the free surface.

As a first step in developing a fundamental understanding of the cavitation erosion process on polymer surfaces, this thesis explores simulation of the collapse of individual bubbles against a compliant surface e.g. metallic substrates with polyurea coatings. The surface response of collapse-driven impact loads is represented by a idealized, time-dependent, Gaussian pressure distribution on the surface. A two-dimensional distribution of load radii and durations is considered corresponding to characteristic of cavitating flows accelerated erosion experiments. Finite element simulations are performed to fit a response curve that relates the loading parameters to the energy dissipated in the coating and integrated with collapse statistics to generate an expected heat input into the coating.

The impulsive pressure, which is generated due to bubble collapse, impacts the material and generates intense shock waves that result in cyclic stress loading. The stress waves within the material reflects by interaction with the substrate. A transient region of high tensile stress is produced by the interaction of these waves. Simulations suggests that maximum hydrostatic tension which cause failure of polyurea layer is observed in thick coating. Finally, the rate of dissipated viscous energy and corresponding temperature rise in a polyurea is calculated, and it is concluded that temperature has influence on deformation.

April 13, 2015; 3:00 PM; GWC 109