CLOUD CAVITATION ON AN OSCILLATING HYDROFOIL

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ABSTRACT

Cloud cavitation, often formed by the breakdown and collapse of a sheet or vortex cavity, is believed to be responsible for much of the noise and erosion damage that occurs under cavitating conditions. For this paper, cloud cavitation was produced through the periodic forcing of the flow by an oscillating hydrofoil. The present work examines the acoustic signal generated by the collapse of cloud cavitation, and compares the results to those obtained by studies of single travelling bubble cavitation. In addition, preliminary studies involving the use of air injection on the suction surface of the hydrofoil explore its mitigating effects on the cavitation noise.

NOMENCLATURE

c = Chord length of foil (m)
I = Acoustic impulse ($Pa \cdot s$)
I^* = Dimensionless acoustic impulse
k = Reduced frequency = $\omega c/2U$
p = Test section absolute pressure (Pa)
$\overline{p}$ = Time averaged pressure (Pa)
p_a = Radiated acoustic pressure (Pa)
p_A = Acoustic pressure intensity (Pa)
p_v = Vapor pressure of water (Pa)
q = Normalized air flow rate = Q/Ucs
Q = Volume flow rate of air at test section pressure and temperature (m^3/sec)
$\mathcal{R}$ = Distance between noise source and hydrophone (m)
s = Span of foil (m)
t = Time (s)
T = Period of foil oscillation (s)
U = Tunnel test section velocity (m/s)
V = Volume of cavitation bubble or cloud (m^3)
α = Instantaneous angle of attack of foil (deg)
$\overline{\alpha}$ = Mean angle of attack of foil (deg)
ρ = Fluid density (kg/m^3)
σ = Cavitation number = $(p - p_v)/\frac{1}{2}\rho U^2$
ω = Foil oscillation frequency (rad/s)

INTRODUCTION

In many flows of practical interest one observes the periodic formation and collapse of a "cloud" of cavitation bubbles. The cycle may occur naturally as a result of the shedding of bubble-filled vortices, or it may be the response to a periodic disturbance imposed on the flow. Common examples of imposed fluctuations are the interaction between rotor and stator blades in a pump or turbine and the interaction between a ship's propeller and the non-uniform wake created by the hull. In many of these cases the coherent collapse of the cloud of bubbles can cause more intense noise and more potential for damage than in a similar non-fluctuating flow. A number of investigators (Bark and van Berlekom [1], Shen and Peterson [2], Bark [3], Franc and Michel [4] and Kubota *et al.* [5, 6]) have studied the complicated flow patterns involved in the production and collapse of a cavitating cloud on a hydrofoil. The present paper represents a continuation of these studies.

Previous studies have shown that, as an attached cavity collapses and is shed into the wake, the breakup of the cavity often results in the occurrence of cloud cavitation. The structure of such clouds appears to contain strong vortices, perhaps formed by the shear layer at the surface of the collapsing cavity (see Kubota *et al.* [5], Maeda *et al.* [7]). These clouds then collapse with some violence, often causing severe erosion on the surface and generating significant amounts of noise (Bark and van Berlekom [1], Kato [8], Ye *et al.* [9]). Figure 1 shows two typical examples of cloud cavitation on the oscillating hydrofoil used in the current study.

One of the present goals was to relate the characteristics of the acoustic signature of a cavitating cloud to the dynamics of the associated collapse process. The details of the cavity growth and collapse and cloud formation are discussed by previous authors, including McKenney and Bren-