Using Data-Driven Reduced Order Methods as a Post Processing Tool to Understand Cavitating Flow Induced Noise

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Wakes behind bluff bodies are characterized by the presence of a Kármán vortex street in the far wake region, and an associated vortex shedding frequency as discussed in [1]. A cavitating wake behind a bluff body can experience significant change in the dynamics of vortex shedding depending upon the extent of cavitation. The shedding frequency of a cavitating wake can increase from a non-cavitating condition to attain a peak value, followed by a reduction in shedding frequency of a super-cavity, as discussed in [2]. It has been recently shown in [3] that in such cavitating bubbly flows, the effect of compressibility is important, and the shedding dynamics change when the local wake Mach number approaches unity, as shown in Figure 1. In this study, the acoustic noise of a cavitating wake at conditions corresponding to different shedding frequencies are presented. In addition, flow structures responsible for the observed changes in the acoustic behavior at different frequencies are identified by performing Proper Orthogonal Decomposition (POD), and Dynamic Mode Decomposition (DMD) on time synchronized time-resolved void fraction fields. Based on the findings, the effect of compressibility on the observed cavitation noise spectrum is presented.

Cavitation experiments were carried out in the 9-inch re-circulating water tunnel at the University of Michigan. The tunnel test section area was further reduced into a square cross-section of 7.6 cm by 7.6 cm, to reduce baseline attenuation by the non-cavitating flow. [4] discusses the set-up in detail. Inlet pressure (p_0) and velocity (U_0) at the reduced test section inlet can be changed between 130 – 15 kPa and 4 -10 m/s respectively. For the present study, the inlet velocity (U_0) was set to 6 m/s. The inlet pressure (p_0) was varied between 100 to 15 kPa resulting in a cavitation number range σ_0, defined in Equation 1, of 0.7 to 6.5.

$$\sigma_0 = \frac{(p_0 - p_v)}{\frac{1}{2}\rho U_0^2} \qquad (1)$$

Cavitation in the wake generated by a 15 degree wedge with 25% blockage is studied. Base pressure fluctuations and averaged base static pressure (p_b) were measured. Acoustic measurements of the pressure signatures emitted by the cavities were measured using a Bruel and Kjaer hydrophone. Cavitation events occurring in the wake were observed from the top and side view using two Phantom V10 high-speed video cameras. The cameras were time synchronized with each other and with the unsteady base pressure measurements as well as acoustics. Time resolved X-ray densitometry based void fraction flow field measurements, synchronous with unsteady base pressure and acoustic measurements were also performed. Description of the X-ray densitometry system can be found in [4].

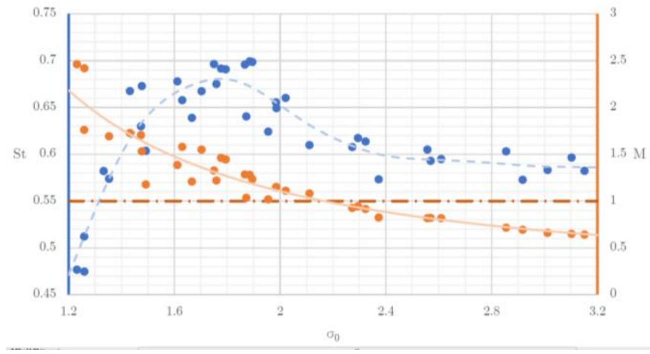

Figure 1. Strouhal number based on wedge base height (Blue) and averaged wake Mach number (Orange) variation with inlet cavitation number. Increase in Strouhal number from non-cavitating value occurs when the local Mach number exceeds unity. Mach number is estimated by using speed of sound expression for a bubbly cavitating flow.

References

[1] Roshko, A., "On the wake and drag of bluff bodies," *Journal of Aeronautical Sciences*, Feb., pp 124-132, 1954,

[2] Young, J. O., and J. William Holl., 1966, "Effects of cavitation on periodic wakes behind symmetric wedges," Journal of Basic Engineering, 88.1, 163-176.

[3] Ganesh, H, Deijlen, L., Bhatt, A., Wu, J., and Ceccio, S. L., "Cavitation Dynamics in Wakes Behind Bluff Bodies", *32nd Symposium of Naval Hydrodynamics*, Hamburg, Germany, Aug. 05 - 10, 2018

[4] Ganesh, Harish, Simo A. Mäkiharju, and Steven L. Ceccio., "Bubbly shock propagation as a mechanism for sheet-to-cloud transition of partial cavities," Journal of Fluid Mechanics, 802, 37-78, 2016,