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Full-scale measurements of a propeller tip vortex cavity and its broadband noise

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ABSTRACT

Tip vortex cavitation (TVC) occurring on ship propellers is a major source of broadband noise emissions that affect both marine life and passengers' comfort. Unfortunately, to the authors knowledge, only one model-scale experimental analysis on propeller isolated TVC has been conducted by Pennings et al. (2016). This lack of data is detrimental to the validation of numerical and empirical models used to estimate broadband induced noise levels. To address this issue, cavitating tip vortices were measured at full-scale on a cruise ship propeller during sea trials, by means of two high speed cameras (resolution: 2560x1000 pixels; framerate 1.10^3 frames per second) synchronized with dynamic pressure sensors (acquisition frequency: 100 kHz) mounted on the hull above the propeller (Fig 1). Three loading conditions corresponding to the adimensional thrust coefficients $Kt = 0.1524, 0.1616$ & 0.1639 were analyzed. The cavity diameter and its oscillations were therefore determined (Fig 2). The general behavior of the vortex cavity dynamic features cavity growth and collapse, eventually followed by rebounds depending on the conditions. The oscillation frequencies and the mean cavity size trends were compared with the estimations of a semi-empirical tip vortex model (ETV) proposed by Bosschers (2018). The results are in fairly good agreement with the prediction from the 2-D Proctor vortex model. In line with the ETV model, the oscillation frequency decreases as the cavity size grows with the blade loading. However, the broadband typical shape in the pressure fluctuations spectrum is not clearly discernible. This experimental study confirms the relevance of the semi-empirical model and provides useful insight on how to assess numerical computations as well as other approaches to tip vortex broadband noise estimation.

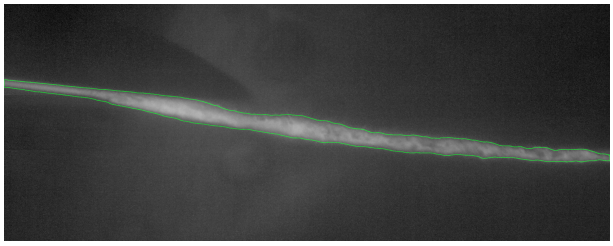

Figure 1: Frame example from case at $Kt = 0.1524$ & $\sigma_{tip} = 4.4$, green line shows the vortex cavity edges. Flow direction from bottom to top of image.

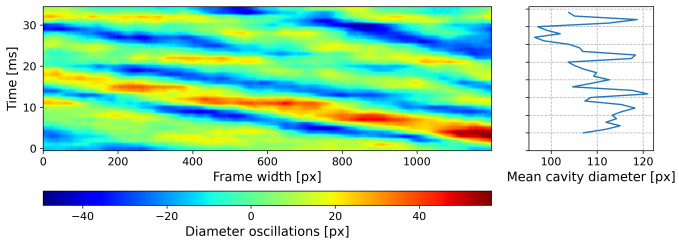

Figure 2: Left: cavity diameter oscillations over one blade passage in cameras view. Right: mean cavity diameter (in pixels) over time.

References

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