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MODELLING OF TIP VORTEX CAVITATION FOR ENGINEERING APPLICATIONS IN OPENFOAM

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Tip vortex cavitation has been studied extensively for an elliptical planform with an aspect ratio of 3, a NACA $66_2 - 415$ cross-sectional shape using an $a = 0.8$ mean line [1]. It was found that at certain cavitation numbers the cavitating tip vortex from this planform emits a strong tonal noise, called vortex singing [2]. The cause of the singing behavior of the vortex cavity is not yet known, but most likely related to excitement of one of its vibration modes, described by [3], due to flow instabilities in the tip region. The excitation of sound generating modes of the cavitating vortex is one of the possible explanations of the high frequency broadband noise generated by more skewed ship propellers, designed to avoid sheet cavitation [4].

In order to gain insight in the accuracy of modelling tip vortex cavitation with RANS equations and the VOF method and get a better understanding in the flow instabilities associated with cavitating vortical flow, the cavitating and non-cavitating tip vortex flow have been modelled with OpenFOAM. The effects of turbulence are modelled with the Spalart-Allmaras model in fully turbulent and transitional form to investigate the effects on the the viscous core size of the vortex. Furthermore, the excessive production of turbulent viscosity in the vortex core, known to lead to too large diffusion for this class of turbulence models, has been significantly reduced with the simple rotation correction proposed by [5].

Calculations were performed at a Reynolds number of 6.8 10^5 and a cavitation number of 1.7 at a geometric angle of attack of 9° (Figure 1). The non-cavitating viscous core size of the vortex was reduced significantly when the transitional formulation was used. Furthermore, it was found that numerical diffusion was low enough to result in a core pressure which can sustain cavitation up to approximately one cord length behind the foil. The rotational correction was found necessary to achieve a cavitating vortex core

by reducing the turbulent viscosity in the core. Modelling errors will be assessed with available experiments [1]. In support of this analysis recent results from experiments performed in the cavitation tunnel facility of the TU Delft on the same geometry are available for comparison and validation. Acoustic, high speed video and force measurements over a range of cavitation and Reynolds numbers have been performed, in order to investigate the oscillation modes of the cavitating vortex.

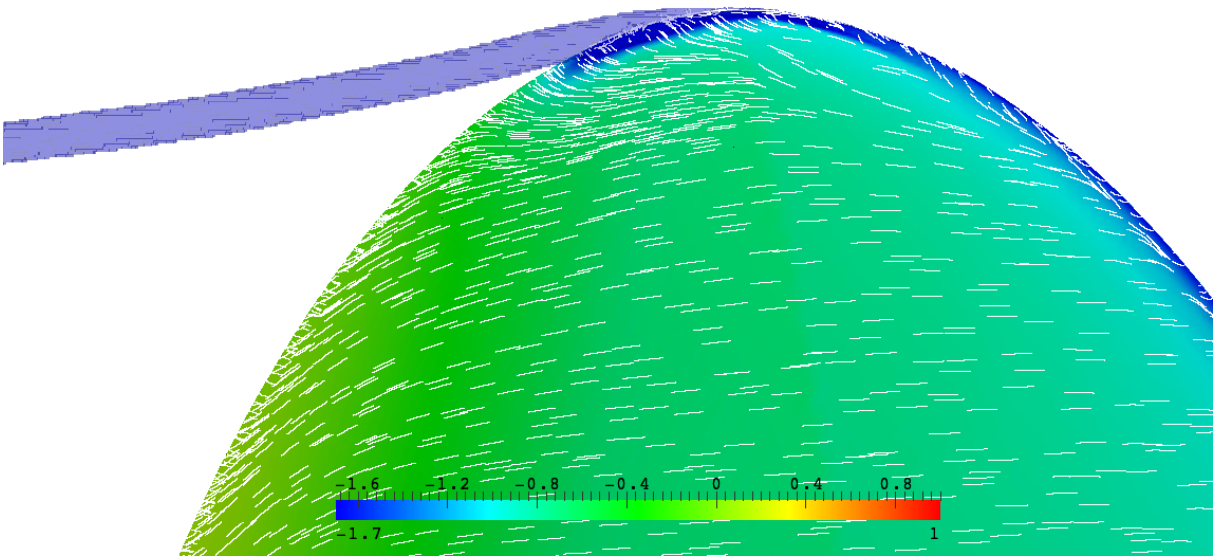

Figure 1: Surface streamlines and pressure coefficient with vapor pressure iso-surface for the non-cavitating transitional case at the suction side near the wing tip.

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