Assignment Report - 2

Vortex Lattice Method - used to find lift generated on a rudder

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Abstract

Vortex Lattice Method is used to calculate numerically the lift generated on a flat rudder held at various angles of attack and is compared with the theoretical lift values obtained using the analytical equation for lift on an infinite plate.

1 Problem Statement

Consider a flat plate rudder of height (span) 5 m and width (chord) 1.5 m of a ship (as shown in Fig. 1). Let the density of water be 1000 [kg/m3]. Neglecting interactions with the wave surface and the ship hull and using the vortex lattice method given in this notes, develop a computer program and determine the lift force generated by the rudder at forward speed Uo = 10 [m/s] for angle of attack 3, 5, 10, 15 and 20^0 . Obtain the result for lattice size of N=9, 20, 50, 100 etc and study convergence. Discuss how the results compare with 2D flat plate analytical result which for this problem is:

$$2\pi\alpha[0.5\rho U_0^2 \times (Chordlength)] \times (Spanlength)$$

Figure 1: Schematic of rudder (source: Notes, Prof. P Ananthakrishnan)

2 Methodology

The domain is discretized into a number of panels. Each panel has a horseshoe vortex whose strength is to be determined using the no flux condition. The velocity induced by the vortex is determined by the Biot-Savart law. The normal velocity of the fluid is known to be $U_0 sin(\alpha)$. The circulation is determined by solving the system of equations and the Kutta-Joukowski theorem is used to calculate the numerical lift force.

$$A_{ij}\Gamma_j = U_0 sin(\alpha)$$

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3 Results

The converged values of numerical lift (using 500 panels) is plotted along with the theoretical lift values for various angles of attack in Fig 2.

Figure 2: Numerical and Theoretical Lift force for angles of attack (marked by the squares) of 3,5,10,15, and 20^0.