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Validation of the Neumann-Michell Theory for Two Catamarans

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ABSTRACT

Numerical predictions given by the Neumann-Michell linear-potential-flow theory have previously been reported and found to be in good overall agreement with experimental measurements of the drag, the sinkage and the trim experienced by a number of *monohull* ships, as well as the wave profiles along the ship hulls, within a range of (relatively low) Froude numbers. The Neumann-Michell theory has also been widely used for ship hull-form optimization, and found to be a robust practical method useful for design. For further validation, the theory is applied here to two catamarans. Numerical predictions and experimental measurements of the free-surface elevation along a longitudinal cut, the drag, the sinkage and the trim are found to be in good overall agreement for both the 'Delft catamaran model' and the 'Series 60 catamaran model', with (nondimensional) lateral distances $s \equiv S/L$ between the twin hulls of the catamarans equal to 0.167, 0.233, 0.300 (Delft) or 0.226, 0.307, 0.388 (Series 60), within the relatively wide ranges of high Froude numbers $0.3 \leq F \leq 0.8$ (Delft) or $0.3 \leq F \leq 0.55$ (Series 60). The Neumann-Michell theory is also used to compute the wave patterns of the Delft catamaran and the Series 60 catamaran at Froude numbers $0.3 \leq F \leq 1.2$. These computations show that, at high Froude numbers, the largest waves created by the catamarans are found inside the cusp lines of the Kelvin wake due to wave-interference effects, as previously explained by the authors.

KEY WORDS: Neumann-Michell; catamarans; drag; sinkage; trim

INTRODUCTON

Interest in high-speed catamarans has greatly increased in recent years. Indeed, catamarans are superior to monohulls in several respects. In particular, catamarans have lower wave drag, greater transversal stability, and larger deck area. These practical advantages have motivated a significant body of experimental and numerical studies of catamarans. Wellicome et al. (1999); Molland et al. (1994) report a systematic experimental study of drag components, and of the effect of hull separation on the wave drag, for a series of high-speed catamarans with transom sterns, in both deep and shallow water. Zaghi et al. (2011); Souto-Iglesias et al. (2007, 2012) report experimental measurements, performed for CFD validation and to study the influence of the hull-separation distance, for several catamarans. Armstrong (2003) reports wind tunnel experiments that illustrate the influence of hull proximity on the drag. CFD has also been applied to compute the near-field flow and free surface for several catamarans, e.g. He et al. (2011); Miller and Gorski (2006); Souto-Iglesias et al. (2007). Millward (1992); Moraes et al. (2004) report computations based on potential-flow theory for high-speed twin Wigley hulls.

THE NEUMANN-MICHELL THEORY

Practical applications to design, notably at early (concept and preliminary) design stages, and design optimization require computational methods that account for dominant flow physics yet are robust and highly efficient. The Neumann-Michell theory given in Noblesse et al. (2013a,b); Huang et al. (2013) is a practical method, based on linear potential flow theory, that is well suited for ship design and hull-form optimization, as already demonstrated in e.g. Huang et al. (2014a,b); Yang et al. (2014). Indeed, the numerical applications of the theory given in Huang et al. (2013); Yang et al. (2013); Zhang et al. (2014) show that the pressure distribution (and the related wave drag, sinkage and trim) around a ship hull discretized by about 10,000 (flat triangular) panels can be evaluated in about 20 seconds using an ordinary PC. Moreover, the numerical predictions given by the Neumann-Michell linear-potential-flow theory reported in Huang et al. (2013); Yang et al. (2013); Zhang et al. (2014) for *monohull* ships are in good overall agreement with experimental measurements of the drag, the sinkage and the trim experienced by a number of *monohull* ships, as well as the wave profiles along the ship hulls, within a range of Froude numbers. Huang et al. (2013); Yang et al. (2013); Zhang et al. (2014) only consider *monohull* ships and relatively low Froude numbers $F \leq 0.4$.

For further validation, the Neumann-Michell theory is applied here to two high-speed catamarans; specifically, the 'Delft catamaran model' and the 'Series 60 catamaran model'. The Neumann-Michell numerical predictions of the free-surface elevation along a longitudinal cut, the drag, the sinkage and the trim are found to be in good overall agreement with the experimental measurements reported in Zaghi et al. (2011) for the 'Delft catamaran model', with nondimensional lateral distances $s \equiv S/L$ between the twin hulls of the catamarans equal to 0.167, 0.233 or 0.300, and in Souto-Iglesias et al. (2012) for the 'Series 60 catamaran model' with $s = 0.226, 0.307, 0.388$, within the relatively wide ranges of high Froude numbers $0.3 < F < 0.8$ (Delft catamaran) or $0.3 < F < 0.55$ (Series 60 catamaran).