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Computations for a US Navy Frigate Advancing in Head Waves in Fixed and Free Conditions

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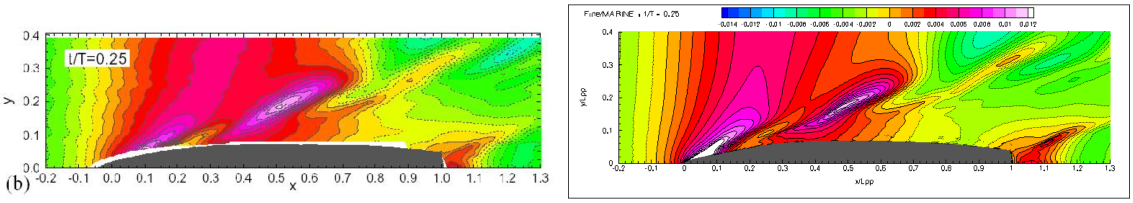
ABSTRACT

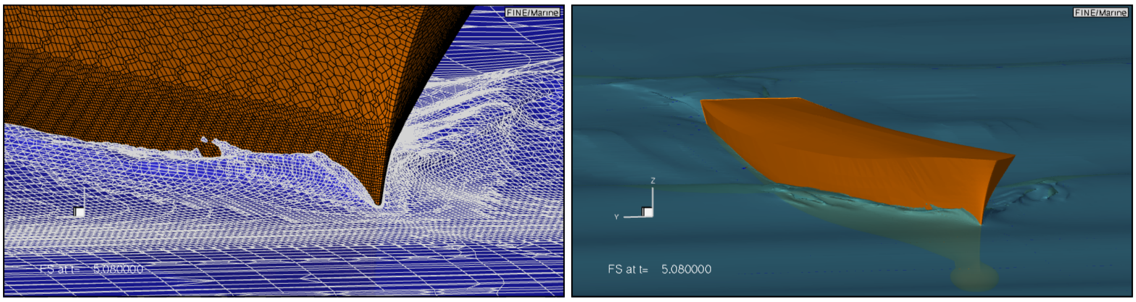
The impressive development achieved, during the last decade, both in hardware and software development, makes now possible the use of viscous solvers to compute full-scale free-surface flows of fully-appended hulls. The robustness of compressive free-surface capturing methodology associated with the flexibility of an unstructured finite-volume discretisation method applied to locally-refined grids, creates a computational environment which can be used to simulate a large variety of flows from moderate to violent breaking waves (see [1] and [2] for recent illustrations). The ship forward speed diffraction problem will be therefore adressed by this paper which will propose a validation study for a US Navy frigate (DTMB 5512) at model scale in various conditions ranging from moderate speed in long and smooth waves (Fr=0.28, $\lambda = 1.5Lpp$ and $Ak = 2\pi\frac{A}{\lambda} = 0.025$) to high speed in short and steep waves (Fr=0.41, $\lambda = 0.5Lpp$ and $Ak = 0.075$). These computations will be conducted with a hull in fixed position or free in trim and sinkage according to the experiments performed by IIHR (see [3]).
The first configuration which will be treated is the flow around the DTMB5512 running in moderate and long waves ($\lambda = 1.5Lpp$ and $Ak = 0.025$) at moderate speed (Fr=0.28). The results of this computation will be extensively compared to the available experiments in terms of time-averaged and phase-averaged free-surface elevations. Two computations with fixed or free in trim and sinkage attitudes will be proposed and compared to the available experimental results. Figure 1 shows a comparison of one phase-averaged free-surface elevation field for a fixed frigate in head waves at $t/T = 0.25$. Thanks to the use of specific compressive discretisation schemes for the mass-fraction transport equation, the agreement between experiments and computations is excellent.



(a) Experiments

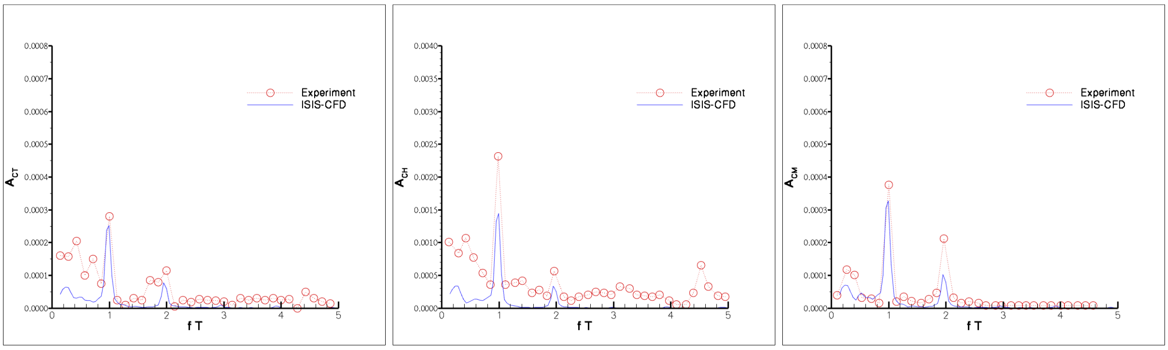
(b) Computations

Figure 1: DTMB5512 - Fr=0.28 - Phase-averaged free-surface elevation at t=T/2



(a) Grid density (b) Bow wave

Figure 2: DTMB5512 in head waves - Fr=0.41 - Instantaneous view of grid and waves at bow



(a) Resistance (b) Heave (c) Pitch moment

Figure 3: DTMB5512 in head waves - Fr=0.41- FFT analysis of the resistance, heave and pitch moment

The second set of configurations concerns the flow around the fixed DTMB5512 running in short and steeper waves ($\lambda = 0.5Lpp$ and $Ak = 0.075$) at high speed (Fr=0.41). Contrary to the previous configuration, this test case is characterised by higher non-linear effects associated with breaking waves at the bow and spilling breaking stern waves associated with a pronounced rooster tail and dry transom configuration. Figures 2, illustrate the breaking wave phenomena appearing at the bow and the local grid refinement used here to capture wave breaking.

Finally, Figure 3 shows a compared FFT analysis performed on the resistance, heave and pitch moment. The computations capture quite accurately the first and second harmonics expressed in terms of encounter frequency, although the contents of the computed signals are less rich in low frequencies than in the experiments. In the final version of the paper, one will also treat both configurations including free pitch and heave motions.

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