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Suppression of transients in wave-excited response testing

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ABSTRACT

When a floating body in a wave tank has low hydrodynamic damping, for example in the heave mode, very long duration transient responses can arise if it is excited from a state of rest by sinusoidal waves. Such behaviour can be undesirable when steady state response characteristics are the object of investigation in a numerical tank, because of the consequential need for very long computations. The present paper develops a method for suppressing such transient behaviour in computational models. The success of the approach is demonstrated in the context of the heaving motion of a simple buoy. A linear model of such a buoy initially at rest in a wave tank, excited by propagating sinusoidal waves, is used here for a preliminary investigation of the removal of transients. The technique is then incorporated into a fully nonlinear potential flow simulation of the buoy, and the approach is shown to be effective.

1. Introduction

Since the time of the pioneering publication by St Denis and Pierson (1953), it has become common practice to assess the behaviour of marine structures in irregular waves using the building block of physical model tests and calculations in regular sinusoidal waves. Transfer functions, also known as Response Amplitude Operators (RAOs), are used to determine power spectra of responses (e.g. motion response, stress, and diffracted free surface elevation) in random waves. From these spectra, mean square and extreme statistics may be estimated. More recently, there has been interest in assessing wave energy conversion systems. For concept development, model validation and performance optimisation of such devices, regular wave testing plays a very important role, as emphasised for example in the pertinent Marine Renewable Energy Guide (Holmes, 2009) and in ITTC (2011a). This paper addresses a difficulty that can arise in model testing (in both physical and numerical wave tanks) when the length of time after the wavemaker has been started until the time when the steady state has been reached is undesirably long (see for example Yan and Ma, 2007). Reasons why shorter lengths of tests may be desirable might include the problem of reflections from side and end walls eventually corrupting the steady state response being sought; and the avoidance of excessively long computer runs in numerical tanks or open ocean simulations. The former matter is highlighted by the following extract from ITTC (2002): “In order to have the best possible quality waves, the interval to be analysed should be sufficiently early in the time series, i.e. the time interval before the reflected waves reach the model. On the other hand, in case of large start-up transients, one may have to accept wave reflections so

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that the analysis will not be disturbed too much by the transients". The latter is exemplified by one of the conclusions in ITTC (2011b): "One immediate challenge comes from more compute-intensive application areas like seakeeping that requires an extremely long solution (simulation) time and a very large parameter space (operating conditions) to be covered in simulations. For those applications, the speed of present day CFD solutions is considered far too slow to satisfy the requirement in terms of solution time and to impact design at an early stage." Physically the problem is particularly likely to arise if the response under investigation is very lightly damped: e.g. the heave motion of a compact floating body such as a buoy or a component of certain designs of wave energy converter (Falnes and Hals, 2012).

The phenomenon under consideration may best be introduced by means of the example of a floating buoy free to move vertically in heave but constrained from all other motions. Fig. 1 shows results from simulations of the linear response of such a buoy, comprising a truncated vertical cylinder, placed in a long wave tank. The data are given for a wavemaker oscillating with a period of 9 s, a typical full scale period of the swell exciting a wave energy converter in operational conditions. Details of the buoy and of the simulation are given below: here we introduce the characteristics of the resulting responses. Fig. 1(a) shows the time history of the wave as recorded at a position 280 m from the wavemaker, with no body present in the tank. It is found that after about 90 s the wave elevation varies harmonically with a period of 9 s. Prior to that there is a transient during which the amplitude of oscillations increases gradually; and before about 25 s there is no detectable disturbance of the free surface: the wave has not yet propagated the 280 m to the recording position. The form of the transient depends on the distance from the wavemaker, because the individual wave components which make up the transient wave front are dispersive; the longer wavelengths propagate faster than the shorter ones. The transient behaviour also depends on whether a ramp function has been applied to the wavemaker, as sometimes implemented to minimise numerical problems associated with modelling an impulsive start to the motion.

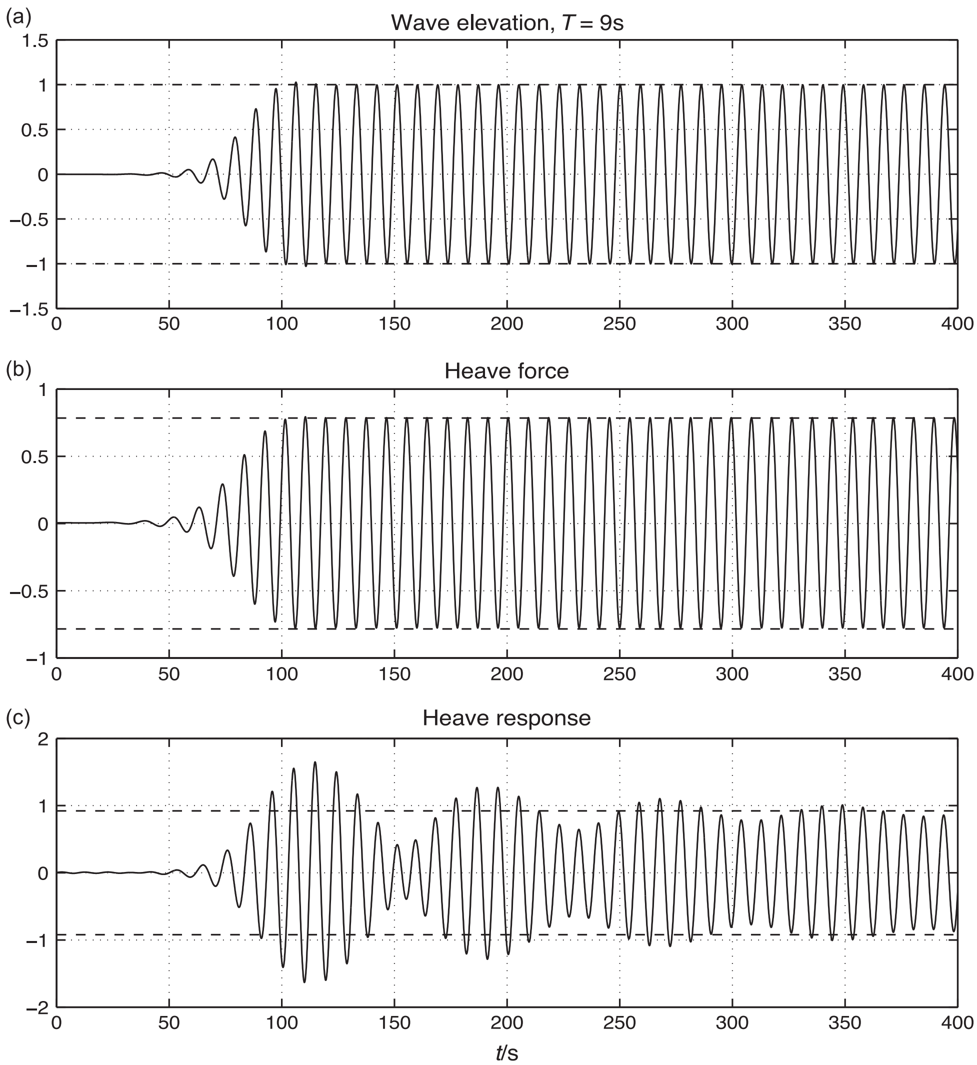

Fig. 1. Transient wave and response time histories over 400 s, for a wave period of 9 s. (a) Incident wave elevation; (b) heave force on buoy; (c) heave response.