An experimental investigation of ringing loads on a vertical cylinder in transient waves

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Over the last ten years considerable efforts have been made to analyze wave loads which lead to sudden high frequency responses of floating or stationary offshore platforms. Several model tests and small scale experiments have been undertaken. Perturbation methods and fully nonlinear methods have been developed to deal with the phenomenon (see the reference list). It seems, however, that a thorough understanding of this problem is still lacking.

Recently, we have performed several small scale experiments on slender vertical circular cylinders in incoming periodic waves (Huseby & Grue, 2000). The periodic results are, however, not the focus here. We observed in these experiments that rather intense higher harmonic oscillations of the force acting on the cylinder happen due to the transient leading part of the wave train. The oscillations of the resulting forces are much more pronounced in the transient part of the waves than in the periodic part. This typically occurs for rather steep waves. The behavior of the measured forces is similar to the forces observed in focused waves with large elevation (Grue *et al.*, 1993; Chaplin *et al.*, 1997).

This has motivated us to study these waves and the resulting forces more closely. The leading wave of a periodic wave train is large and transient. We use PIV to measure velocity and acceleration fields of the waves, considering variation in both time and space. The PIV measurements are combined with amplitude and force measurements on cylinders of different radii.

Experiments and results

The measurements are carried out in a wave tank which is 24.6 m long, 0.5 m wide and filled with water to a depth of 0.6 m. In one end of the tank there is an absorbing beach. At the other end there is a wave maker which is a vertical plate controlled and monitored by a computer. The movement of the wave maker can be described by the displacement $\xi(t)$ from the mean position, as a function of time (t). This displacement is given as sine function multiplied by a time dependent amplitude function, i.e.

$$\xi = \xi_1 \left(\frac{1}{2} + \frac{1}{2} \tanh \left[(2t - 1) \tanh^{-1} (0.98) \right] \right) \sin(2\pi f t), \qquad (1)$$

where f is the frequency of the wave maker and ξ_1 the amplitude for large t. This means that $\max(\xi) = 0.99\xi_1$ after 1 second.

We consider the leading transient part of the wave train and the resulting force on the cylinder. We use PIV to measure the velocity and acceleration fields of the waves for several different frequencies. Here we present results for two frequencies. These wave measurements are performed without the cylinder present in the tank. When the wave measurements are completed, the cylinder is mounted in the tank for subsequent force recordings. The incoming waves were measured at the position of the cylinder.

We use two cylinders of radius $R = 3$ and $R = 6$ cm. Both cylinders extend to the entire water depth. The distance from the wave maker to the cylinder is 13.12 m. The total force $F(t)$ in the horizontal direction is recorded by two force transducers, and we refer to the sum of these two as the total force.

For the small cylinder we get a large rapid oscillation of the force for both frequencies (figure 1). This is an oscillation that we believe will lead to ringing behavior of offshore structures. The oscillation of the force appears as the wave leaves the cylinder. For the large cylinder a rapid oscillation occurs for the longest waves, while no such oscillation occurs for the shorter waves. This indicates that the oscillation of the force is not only caused by the incoming waves, but also depends on the presence of the cylinder in the waves. Typically the larger cylinder experiences these kind of "ringing loads" for a range of wave lengths that is larger than for the smaller cylinder.

Measurements of the fluid accelerations of the incoming waves, at the position of the cylinder, are then shown. The accelerations are shown as a time series at a geometric point in the wave tank. The accelerations are a mean over 1 cm in depth, 4.4 cm under the mean water level, at the position of the cylinder. In order to obtain the time series, the PIV system is triggered each 1/100 of a second. For each 31 time steps a mean of 5 independent runs in the wave tank is obtained. The lower plot in figure 2 represents 155 independent PIV measurements. There do not seem to bee any rapid oscillations of the accelerations, as a function of time, indicating that the rapid oscillations of the force are not caused by oscillations in the incoming acceleration field.

At the workshop more results will be presented.

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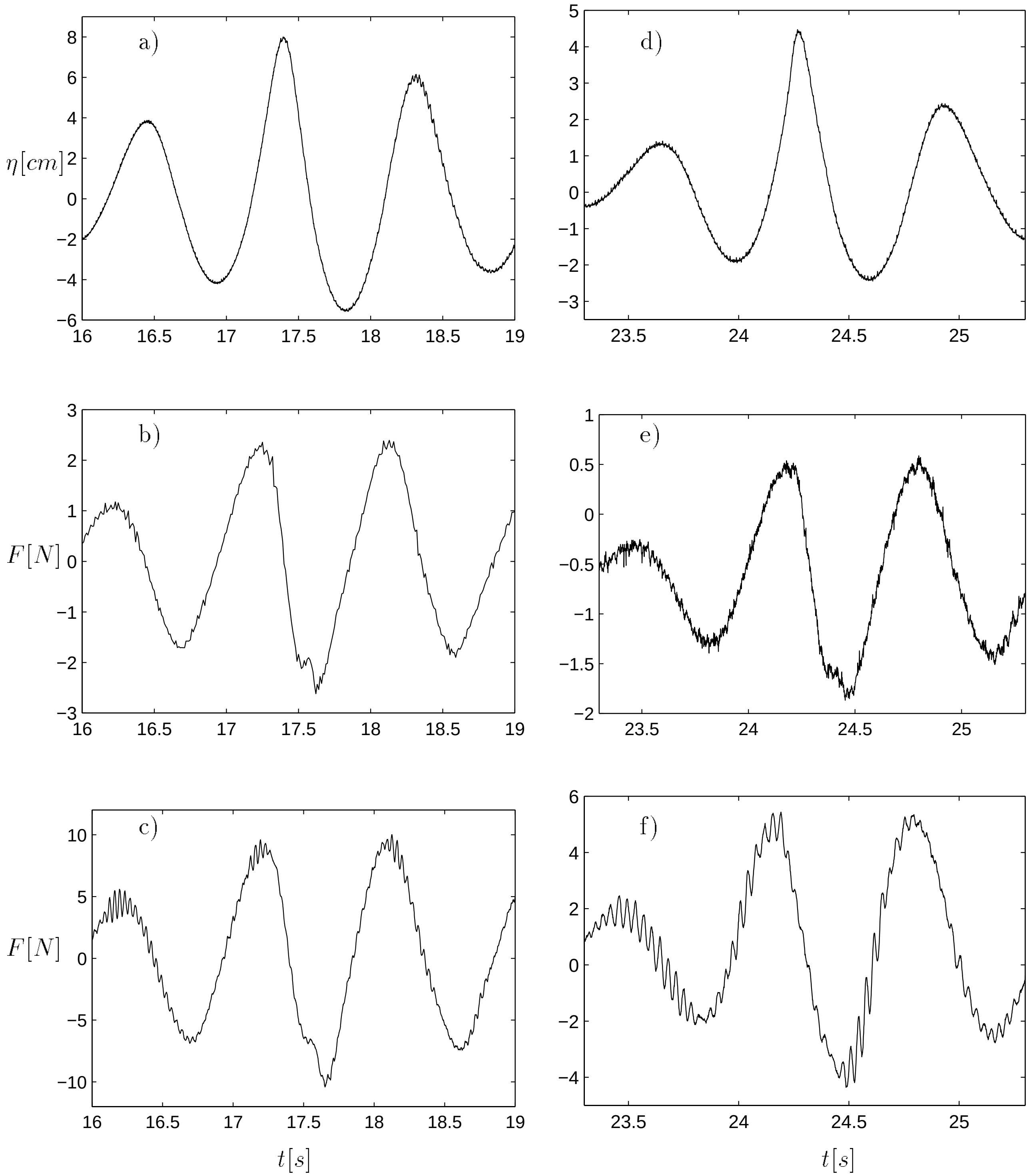

Figure 1: a), b) and c): f=1.0 Hz, $ak = 0.19$ (ak from the steady wave train). d), e) and f): f=1.425 Hz, $ak = 0.18$. a) and d): Time history of the wave elevation. b) and e): Time history of the force for the small cylinder ($R = 3$ cm). c) and f): Time history of the force for the large cylinder ($R = 6$ cm).

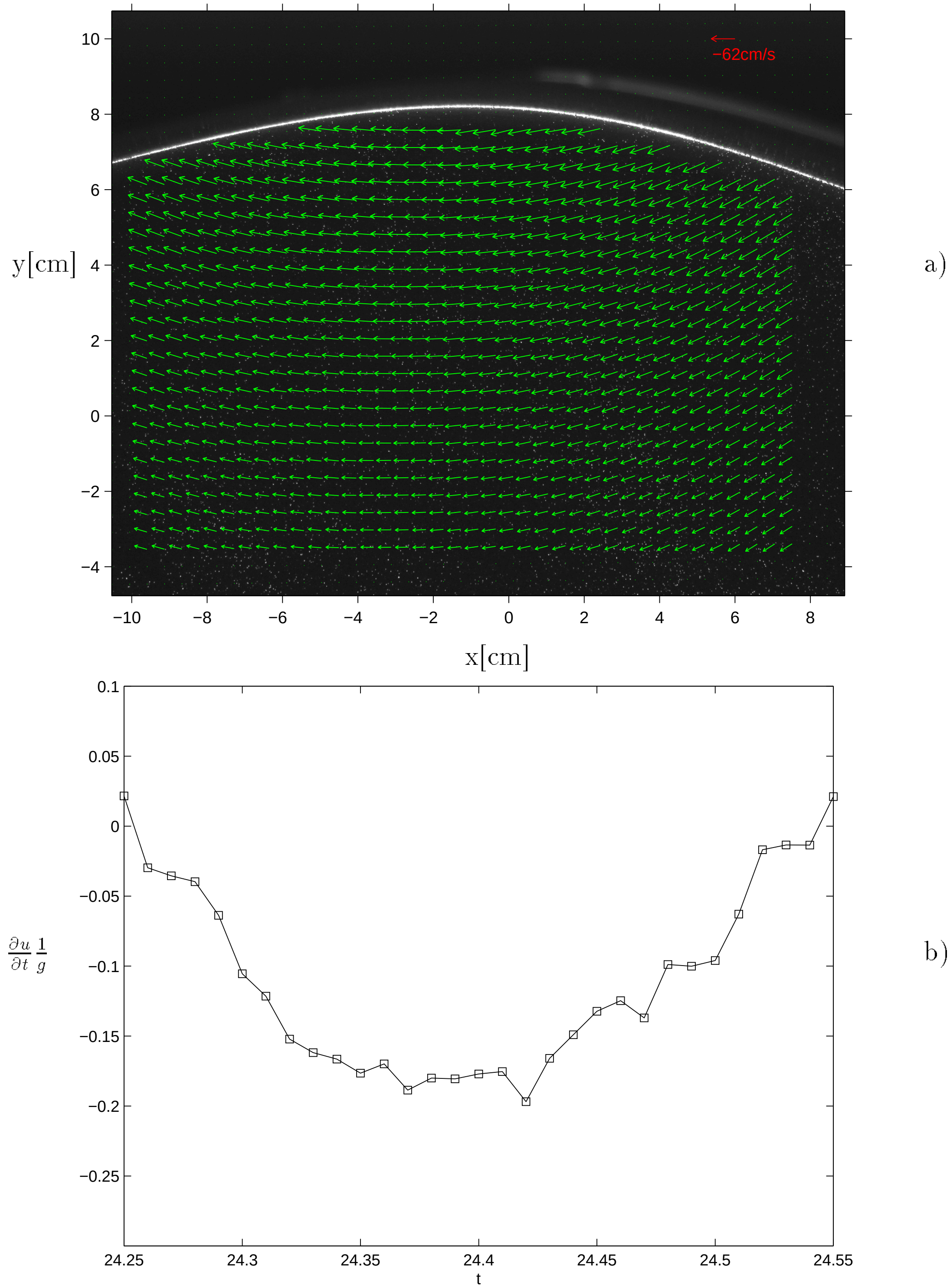

Figure 2: a): Velocity field. Waves with f=1.0 Hz, $ak = 0.19$ (ak from the steady wave train) and $g/\omega = 156$ cm/s. b): Time development of the acceleration. Each point is a separate run and is the mean of 1 cm in depth. Waves with f=1.425 Hz, $ak = 0.18$.