Modelling of wake effects and power absorption of a farm of Wave Energy Converters (WECs)

Introduction

A single Wave Energy Converter (WEC), with a power capacity comparable to a classic power plant (e.g. 400 MW), is technologically impossible. Therefore arrays of smaller devices, placed in a geometric configuration or 'farm', are needed.

WECs in a farm interact and the overall power absorption is affected. Furthermore the cost of a farm is governed by its layout. An optimal pattern of WECs in order to maximize the power absorption at a reasonable cost is of major importance in the design of a wave farm. The absorption of a farm of interacting wave power devices is studied in the mild-slope wave propagation model MILDwave (developed at Ghent University).

Methodology

A single wave energy converter of the overtopping type has been modelled as an absorbing structure with the same reflection, transmission and absorption characteristics as obtained for the prototype WEC. To calculate the power absorbed by a farm of WECs a procedure of adaptive absorption (adapting the amounts of absorption, reflection and transmission of each WEC in the farm to its incident wave power) has been developed. In a first step only the first row of WECs is simulated. By measuring the remaining wave height behind the first row of WECs the performance of a second row of WECs is determined. In a second step the first two rows of WECs are installed and the remaining wave height behind these two rows is calculated. This approach is repeated to obtain the amount of absorbed wave power of a farm of multiple rows of WECs.

Results

Some typical examples of the wake behind a single hypothetical WEC of the overtopping type of 36 m x 36 m are shown in Figure 1 and 2 for irregular long-crested and short-crested waves (spreading s_{max} = 10) respectively, with H_s = 1 m and T_p = 5.2 s. The hypothetical WEC has a prescribed capture ratio of 45 % and a prespecified overall reflection coefficient of 0.14 for a sea state with H_s = 1 m and T_p = 5.2 s. The capture ratio is defined as the ratio between the absorbed power and the incident power on a wave-front width equal to the width of the WEC.

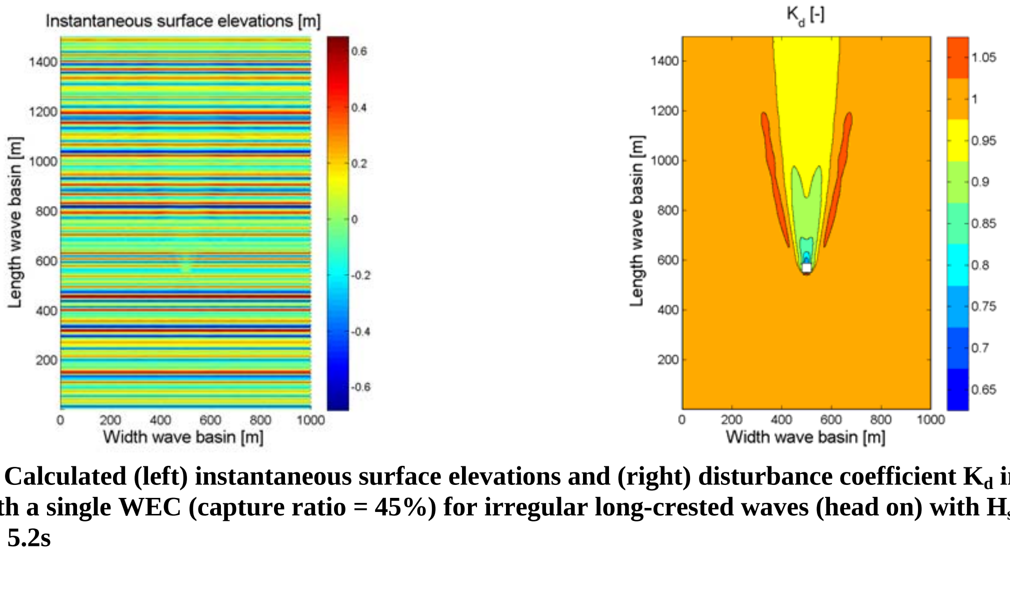

Figure 1 Calculated (left) instantaneous surface elevations and (right) disturbance coefficient K_d in a wave basin with a single WEC (capture ratio = 45%) for irregular long-crested waves (head on) with H_s = 1m and T_p = 5.2s

The length of the wake shortens and the remaining wave height behind the WEC is higher for short-crested waves.

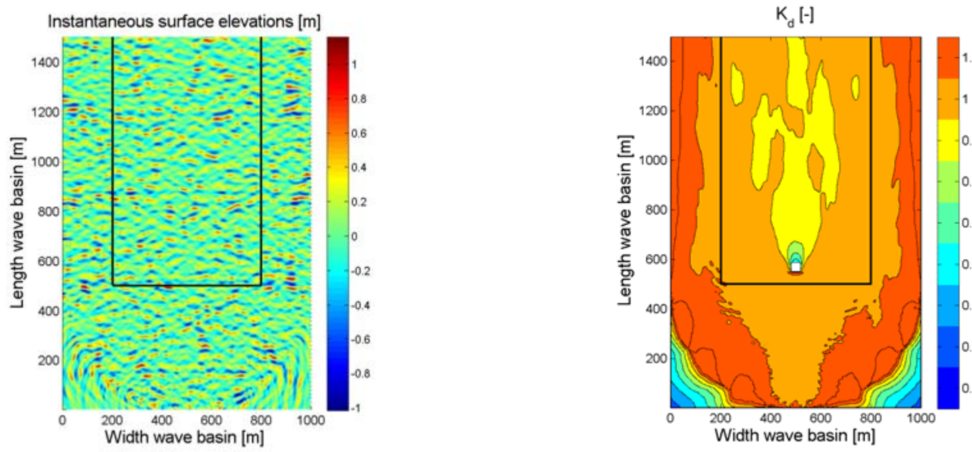

Figure 2 Calculated (left) instantaneous surface elevations and (right) disturbance coefficient K_d in a wave basin with a single WEC (capture ratio = 45%) for irregular short-crested waves (head on – useful domain indicated with black lines) with H_s = 1 m, T_p = 5.2 s and s_{max} = 10

The wake behind a farm of nine hypothetical WECs is shown in Figure 3 for irregular long crested and short-crested waves (spreading s_{max} = 10) with H_s = 1 m and T_p = 5.2 s. All WECs have a capture ratio of 45 % when irregular long-crested waves are generated, as the wave height in front of the WECs equals 1 m. For short-crested waves, the wave height in front of the first and second row equals 1 m, but the wave height in front of the third row is approximately 0.9 m. A capture ratio of 35 % has been assumed for an incident wave height of 0.9 m. The power absorbed by 9 WECs equals respectively 9U and 7.66U for irregular long-crested and short-crested waves, with U the power absorbed by a single WEC. When swell waves are dominating a wake similar to the wake shown in the left part of Figure 3 will occur. On the other hand the wake in the right part of Figure 3 will be observed when wind waves are generated.

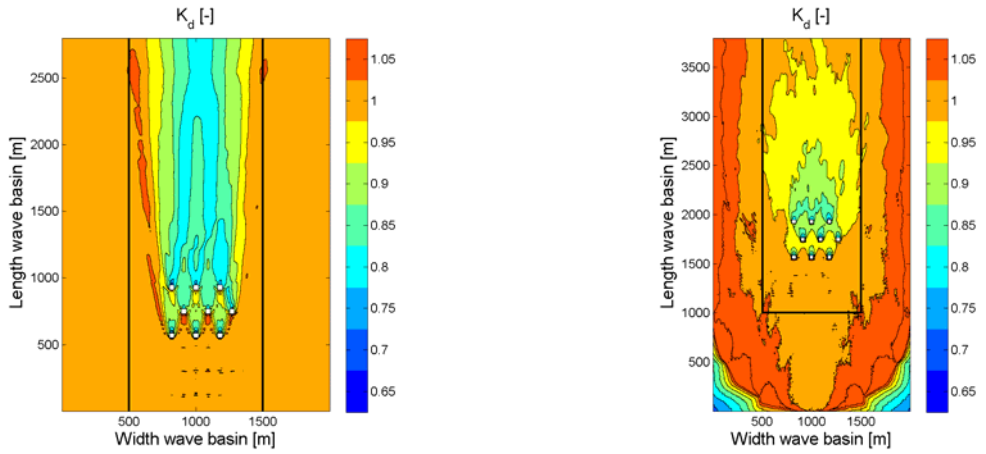

Figure 3 Calculated disturbance coefficient K_d in a wave basin with 9 hypothetical WECs (capture ratio 45 %) in a staggered grid with an in-between distance of 2D, for irregular (left) long-crested and (right) short-crested waves (s_{max} = 10 – useful domain indicated with black lines) head on waves with H_s = 1 m and T_p = 5.2 s

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