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A database of capture width ratio of wave energy converters

A. Babarit

LHEEA Lab, Ecole Centrale de Nantes – CNRS, 1 rue de la Noe, 44300 Nantes, France

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ABSTRACT

The aim of this study is to establish a database for the hydrodynamic performance of Wave Energy Converters (WECs). The method relies on the collection and analysis of data available in the literature. The availability and presentation of these data vary greatly between sources. Thus, extrapolations have been made in order to derive an annual average for the capture width ratio (CWR) of the different technologies. These CWR are synthesized in a table alongside information regarding dimension, wave resource and operational principle of the technologies. It is observed that CWR is correlated to operational principle and dimension. Statistical methods are used to derive relationships between CWR and dimension for the different WEC operational principles.

1. Introduction

Since the early 1980s, hundreds of Wave Energy Converters (WECs) have been studied and developed. Full-scale prototypes have been tested, and technology review papers have been published (see for example [1–8]). These papers usually discuss the technologies, their classifications and technical aspects (e.g. the Power Take-off (PTO) system). They do not discuss power performance of the different wave energy technologies.

Information on power performance can be found in the literature, however in general, the information provided by any given paper is limited to the one technology being investigated. A few studies have compared power performance between different technologies, but they cover a limited number of devices [9–12].

Thus, the aim of this paper is to create an extensive database for the hydrodynamic performance of WECs by reviewing power performance results available in the public literature. In this paper, the approach elaborates and extends on the work by Ref. [13]. Power performance is quantified in terms of capture width ratio (CWR), which is reported for each device in Tables 7–9. To identify trends, the results were classified according to WEC operational principle. A relationship between dimension and CWR was identified and discussed in the last part of this paper.

It must be acknowledged that making an objective comparison of CWR across WEC technologies is not an easy task. In this work, it has been necessary to make assumptions and approximations in order to address issues related to discrepancies in the collected data. These are discussed in Section 2 and Section 4, and are believed to be reasonable. However, it is nevertheless possible that they may influence the final results in Section 4. Since all assumptions and approximations made have been described in detail in this paper, the extent of this influence may be assessed in future work.

2. Methods

The sources for the present work are references [9–11] and [14–45], which present performance results for various WECs. The performance measure used and the way in which results are presented vary greatly from one source to another. Thus, for the purpose of comparison, it was necessary to select a common performance measure, namely annual average of CWR. Note that CWR may also be referred to in the literature as "'non-dimensional performance"' [12].

2.1. CWR

Capture width (CW) was first introduced in 1975 by Ref. [46]. It is defined as the ratio of absorbed wave power P (in kW) to the wave resource J (in kW/m):

$$CW = \frac{P}{J} \tag{1}$$

The unit of capture width is a length in metres. It may be

E-mail address: aurelien.babarit@ec-nantes.fr.

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Table 1
Summary of performance results for the WEPTOS technology studied in Refs. [32–34].

Technology	Operational principle	η_1	Dimension (m)		Resource (kW/m)
WEPTOS	Variation of fixed OWSC	8	2.9	Width	6
		10	2.9	Width	16
		12	3.6	Width	6
		12	3.6	Width	16
		19	4.8	Width	6
		15	4.8	Width	16
		15	5.4	Width	9
		25	6.0	Width	6
		19	6.0	Width	16
		32	8.3	Width	16
		22	9.6	Width	29
		25	9.6	Width	26

Table 4
Performance results for technologies studied in Ref. [10].

Technology	Operational principle	η_1	Dimension (m)		Resource (kW/m)
AquaEnergy/ AquaBuOY	Heaving device	[10–26]	6	Diameter	[12–26]
Energetech	OWC	58	35	Width	[12–26]
INRI/SEADOG	heaving device	[16–24]	5.7	Diameter	[12–26]
Ocean Power Delivery/ Pelamis	Variant of heaving device	[14–21]	15	Characteristic diameter	[12–26]
ORECON/MR1000	OWC	[176–281]	32	Diameter	[12–26]
TeamWork/AWS	Variant of heaving device	[138–205]	9.5	Diameter	[12–26]
Wavebob	Heaving device	[40–51]	15	Diameter	[12–26]
Wavedragon	Overtopping	[21–26]	24	Width	[12–26]

Table 2
Performance results for technologies studied in Ref. [43].

Technology	Operational principle	η_1	Dimension (m)		Resource (kW/m)
NEL Terminator	OWC	55	22	Width	30
NEL Floating Terminator	OWC	24	22	Width	54
NEL Floating Attenuator	OWC	41	20	Width	54
Vicker's Terminator	Variant of OWC	34	30	Width	36
Vicker's Attenuator	Variant of OWC	16	30	Width	36
Belfast Point Absorber	Variant of OWC	35	29	Outer diameter	42
Edinburgh Duck	Variant of OWSC	47	37	Width	54
Bristol Cylinder	Variant of OWSC	46	75	Width	48
Lancaster Flexible Bag	Variant of OWSC	9	20	Width	51
Lanchester Clam	Variant of OWSC	23	27	Width	51

Table 5
Performance results for technologies studied in Ref. [11].

Technology	Operational principle	η_1	Dimension (m)		Resource (kW/m)
Small bottom-referenced heaving buoy	Variant of heaving device	[3–4]	3	Diameter	[15–37]
Bottom-referenced submerged heave-buoy	Heaving device	[8–13]	7	Diameter	[13–34]
Floating-two body heaving converter	Heaving device	[27–36]	20	Diameter	[15–37]
Bottom-fixed heave-buoy array	Heaving device	[12–17]	5	Diameter	[13–34]
Floating heave-buoy array	Heaving device	[6–11]	8	Diameter	[15–37]
Bottom-fixed oscillating flap	Fixed OWSC	[58–72]	26	Width	[13–34]
Floating three-body oscillating flap	Floating OWSC	[7–13]	19	Width	[15–37]
Floating OWC	OWC	[22–35]	24	Width	[15–37]

interpreted as the width of wave crest that has been completely captured and absorbed by the WEC.

More than capture width, it is hydrodynamic efficiency that best reflects the hydrodynamic performance of a WEC. A measure of the hydrodynamic efficiency is the CWR, obtained by dividing the capture width by a characteristic dimension B of the WEC – often the device width. CWR, denoted by η_1, reflects the fraction of wave power flowing through the device that is absorbed by the device:

$$\eta_1 = \frac{CW}{B} = \frac{P}{JB} \tag{2}$$

Selection of a relevant characteristic dimension for B is critical in order to make CWR comparable between different wave energy devices. This is discussed further in Section 2.4.

It is important to note that CWR relates to hydrodynamic power performance (energy absorption) and not economical performance (cost of energy). Efficiency in the PTO system and the power conversion chain, as well as fabrication and operation costs, may be such that the most efficient device hydrodynamically speaking

Table 3
Performance results for technologies studied in Ref. [9].

Technology	Operational principle	η_1	Dimension (m)		Resource (kW/m)
Swan DK3	OWC	20	16	Width	16
Bølgehovlen	Overtopping	8	10	Diameter	16
Power pyramid	Variant of overtopping	12	125	Width	16
Wavedragon	Overtopping	23	259	Width	16
Sucking Sea Shaft	Variant of overtopping	3	125	Width	16
Bølgepumpen	Variant of heaving device	6	5	Diameter	16
Point absorber	Heaving device	14	10	Diameter	16
DWP system	Heaving device	20	10	Diameter	16
Tyngdeflyderen	Variant of heaving device	12	30	Characteristic diameter	16
Wave plunger	Variant of fixed OWSC	16	15	Width	16
Poseidon	Unknown	27	420	Width	16
Bølgeturbinen	Wave turbine	4	15	Rotor diameter	16

Table 6
Performance results for technologies studied in Ref. [44].

Technology	Operational principle	Mean absorbed power per flap	η_1	Dimension (m)		Resource (kW/m)
Vertical flaps on fixed supporting frame	Variant of fixed OWSC	240	31	25	Width	30
		450	37	50		
		220	30	25		
Vertical flaps on supporting frame with taut moorings	Floating OWSC	138	18	25	Width	30
		266	18	50		
Vertical flaps on supporting frame with slack moorings	Floating OWSC	58	8	25	Width	30
		128	8	50		
		158	21	25		