Use of a Rectangular Liquid-Filled Bottom-Mounted Distensible Device to Harness Nearshore Wave Power

Nicolas Choplain and John R. Chaplin
School of Civil Engineering and the Environment, University of Southampton
Southampton, UK

ABSTRACT
The present work aims to find out the applicability of the bulge concept used in the Anaconda (Chaplin et al., 2011) on a possible seabed version. The tested model is a long rectangular duct covered with an elastic membrane and placed on the seabed, parallel to wave propagation. The tension in the membrane and its submergence can be varied by pressurising the system. Two configurations were tested: one with closed ends and one with a Power Take-Off system. Measurements were made of pressure in the duct, membrane displacement and capture width and are compared with a theoretical 1D model.

KEY WORDS: rubber membrane, distensibility, wave pressure amplification, power capture.

INTRODUCTION
This study started with the recent developments of the Anaconda which is a new way of extracting energy from ocean waves, based on bulge waves travelling along a distensible rubber tube (Chaplin et al., 2011), filled with water, oriented in the direction of wave travel and anchored head to waves. Oscillations in pressure beneath the waves generate travelling bulges in the tube. The bulge waves grow in the down-wave direction, converting wave energy into internal oscillatory flow that can be used to drive a turbine. The up-wave end of the tube is closed. Tuning is achieved by matching the speed of free bulge waves (a function of the tube’s material properties and geometry) to the phase speed of water waves. This device is designed for placement in shallow waters and to harness nearshore wave power. Offshore locations have always attracted more interest from wave energy developers due to their highest gross energy resource. Although some promising devices use this nearshore wave climate on a seabed base (OYSTER, WaveRoller), few inventions have been designed for nearshore conditions. However, Folley and Whittaker (2009) have recently shown that using the usual definition of wave gross power for a wave farm assessment is not suitable as it does not take into account the directional dependence of the WEC. Hence the net wave power, defined as a wave power for one direction of propagation, is more suitable for evaluating wave energy conversion potential of a certain WEC. Since wave refraction is not a dissipative phenomenon, there is little net wave power density loss from offshore location to nearshore site, making the latter more interesting in terms of wave energy potential than previously thought.

The closed end configuration of the tested model is closely related to devices designed for breakwaters purposes. Cho and Kim (1998) developed an analytical and numerical model for the interactions of a submerged horizontal tensioned membrane with fixed edges as a potential wave attenuator, and verified it with good agreement with experimental data. This membrane was seen to perform better than classical rigid plates and its efficiency lies not in wave blocking, but in radiated waves cancelling out the transmitted ones. Such configuration was later extended to a submerged plane circular membrane (Cho and Kim, 1999) and a horizontal and porous membrane (Cho and Kim, 2000).

Bottom-mounted membranes have also been studied by several authors: Ohyama et al. (1989) modelled and tested a device like a flexible mound, that consisted of a thin elastic membrane bag filled with water and mounted on the seabed. Phadke and Cheung (1999) extended this study to the case where inner and outer fluid are with different densities, while Phadke and Cheung (2003) included membrane material non-linearity (hysteresis). Those two-dimensional studies were later extended to three dimensions by Das and Cheung (2009), whose numerical results agreed fairly well with experimental data from Ohyama et al. (1989). Liapis et al. (1996) studied a similar device but with a semi-circular shape, and Dewi et al. (1996) extended it to a three-dimensional case.