Duct Extension Effect on the Primary Conversion of a Wave Energy Converter "Backward Bent Duct Buoy"

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The primary conversion efficiency of a "Backward Bent Duct Buoy" (BBDB) wave energy converter is measured in two and three dimensional tank experiments. The effect of duct extension on the primary conversion efficiency is investigated by attaching 15cm and 45cm ducts to the normal model. The experimental result shows that the duct extensions reduce the primary conversion efficiency because they reduce the pitching motion of the BBDB.

Key Words : Backward Bent Duct Buoy, wave energy, primary conversion

1. BACKGROUND

Because carbon dioxide emissions have been restricted, fossil fuel-based energy generation is being converted to renewable energy generation. Equipment to utilize wind, tidal, wave, geothermal and solar energy are under investigation.

We have been studying the "Backward Bent Duct Buoy (BBDB)" wave energy converter [1-4]. The BBDB was proposed by Masuda in 1986 [5]. Fig 1 illustrates the concept of a BBDB. A BBDB consists of an L-shaped duct, a buoyancy module, an air chamber, a turbine and a generator. Water comes into the duct through a rear opening and pushes the air in the air chamber. This high-pressure air turns a turbine, generating electricity.

Wave energy is converted to electricity in two steps. First, wave energy is transformed into pneumatic energy. This stage is called the primary conversion. Next, the pneumatic energy is changed into electric energy, and this stage is called the secondary conversion.

This buoy has some advantages. First, the primary conversion efficiency is high. Second, in some frequency ranges, the drift force becomes negative. Usually, the wave comes from this side, and the floating body drifts downstream. However the BBDB drifts upstream in some frequency ranges [6], reducing the mooring force and mooring cost.

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The goal of this paper is to investigate the primary conversion efficiency of the BBDB. The effect of the buoy shape on the primary conversion efficiency was also investigated.

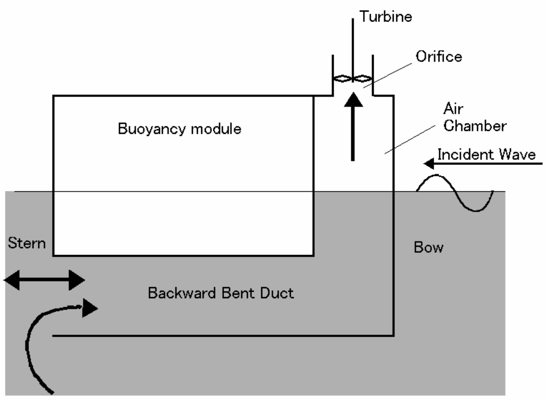

Fig.1 BBDB Concept

2. MODEL EXPERIMENT

Fig2 shows the dimensions of the model, which was made from an aluminum frame and an acrylic board. The model was 0.85m long and 0.78m wide, and had a 0.35m draft. To maintain the buoy's level in the water, 37.5kg of ballast was loaded into the buoyancy module. Two ultrasonic sensors are installed in the air chamber to measure the water level. A pressure sensor was also installed in the air chamber. The sampling interval was 20Hz.

The motion of the model was measured with image processing, using images taken at a sampling interval of 10Hz. The motion of a marker was converted to the motion around the center of gravity.

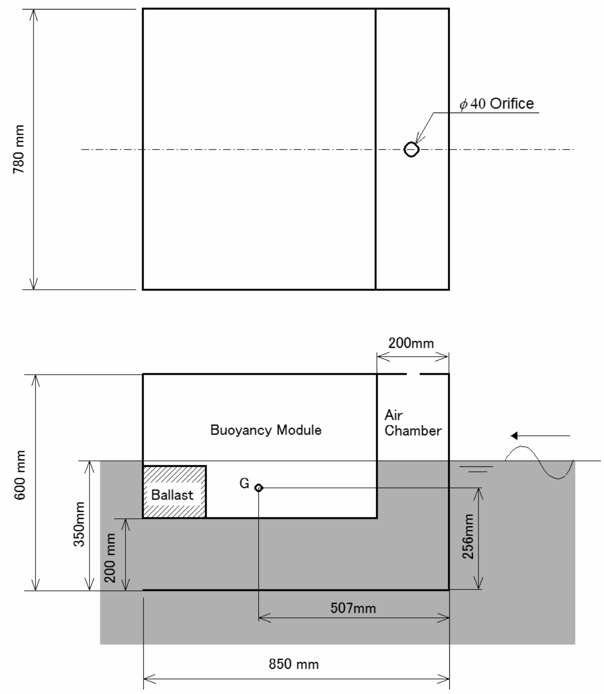

Fig.2 Model dimensions

To investigate the effect of the body shape, the duct was extended by 15cm and 45cm. the duct extensions were attached to the normal body (Fig.3).

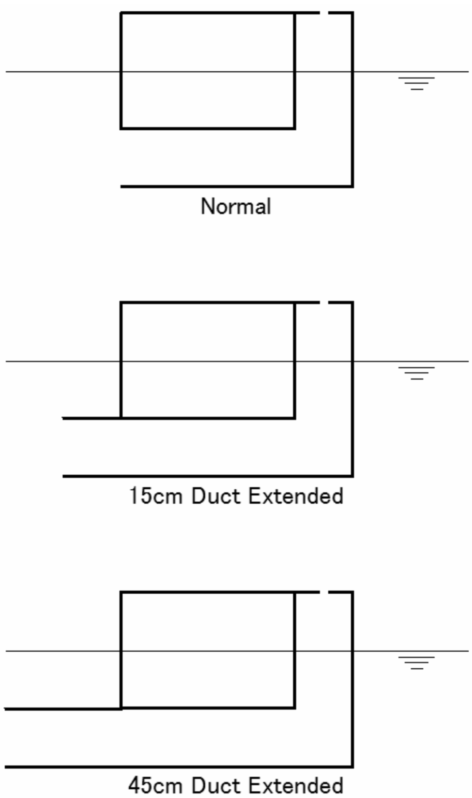

Fig.3 Extended Duct Models

The primary conversion efficiency is investigated in two- and three dimensional tank experiments. Table1 shows the geometry of the tanks. The model was moored in the center of the tanks, and the incident waves, with amplitudes of 2.5-3.0 cm, were made using a wavekmaker.

Table 1 Tank geometry

	Length	Width	Water Depth
Saga University	18.0 m	0.8 m	1.0 m
Kyushu University	65.0 m	5.0 m	7.0 m

The primary conversion efficiency is defined as

$$\eta = \frac{E_{out}}{E_{in}} \tag{1}$$

where E_{in} is the energy flux of the incident wave and E_{out} is the energy flux of the air. E_{in} is defined as

$$E_{in} = \frac{1}{2}\rho g \zeta_i^2 C_g B \tag{2}$$

$$E_{out} = \frac{S}{T}\int_0^T p(t)\frac{\partial}{\partial t}\left(\frac{\eta_1(t)+\eta_2(t)}{2}\right)dt \tag{3}$$

where

ρ	density of water
g	gravity
ζ_i	amplitude of the incident wave
C_g	group velocity
B	BBDB width
S	area of the air chamber
T	period of incident wave
P(t)	pressure in the air chamber
$\eta_1(t)$, $\eta_2(t)$	water level in the air chamber

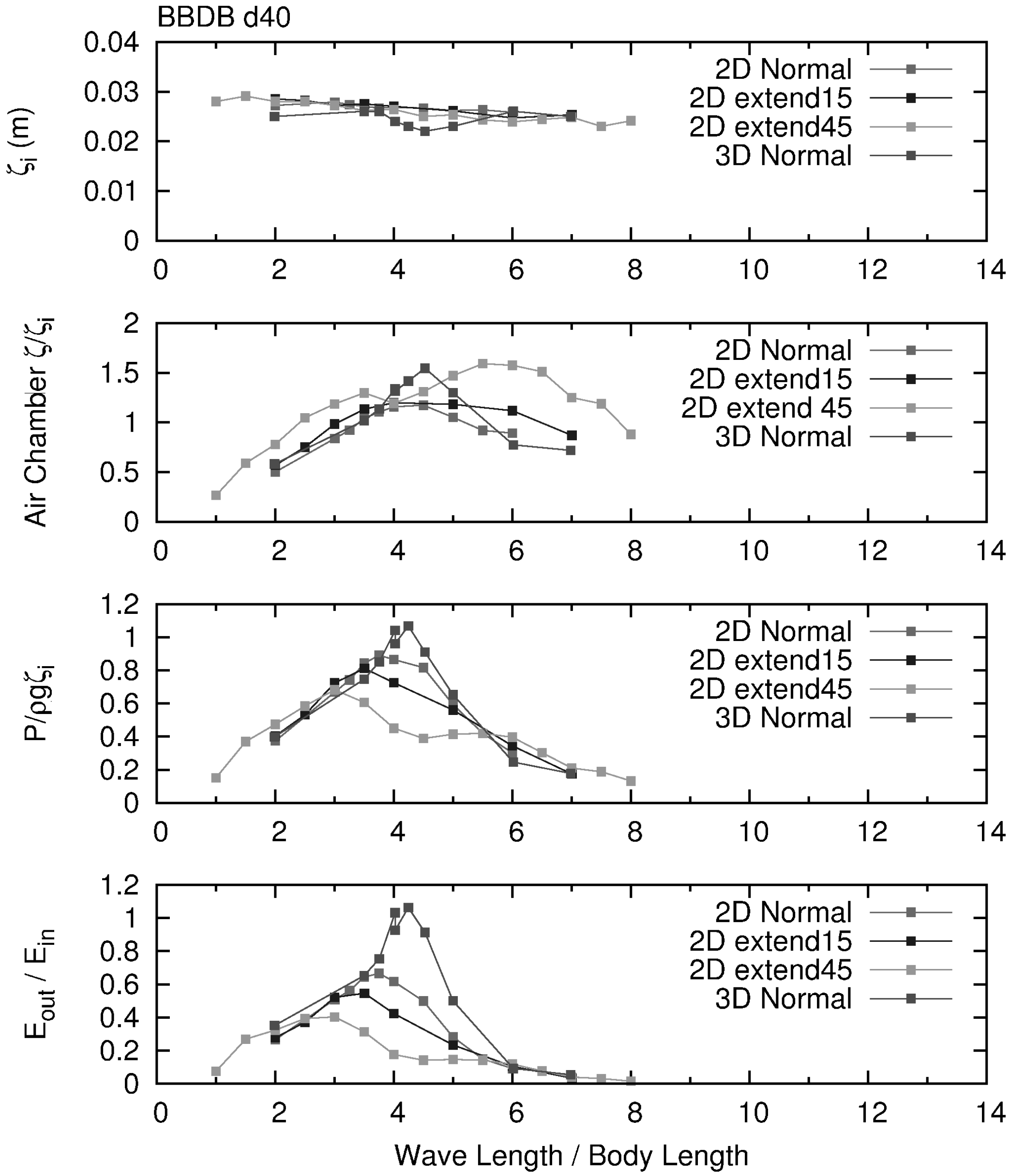

Fig.4 Primary Conversion Efficiency

3. RESULTS

Fig. 4 shows the incident wave amplitude, internal water level, pressure and conversion efficiency. The horizontal axis is defined as the incident wave length (λ) / body length (L). Extending the duct reduces the pressure and, as a result, the primary conversion efficiency is also reduced.

Fig. 5 shows the amplitude of motion. The amplitude is non-dimensionalized, using the incident wave amplitude. This figure shows a large pitching motion is required to achieve a high efficiency.

4. CONCLUSION

The effect of duct extension on the primary conversion efficiency of a BBDB was investigated in two- and three-dimensional tank experiments. The results shows that the duct extension reduces the primary conversion efficiency because it reduces the pitching motion of the BBDB.

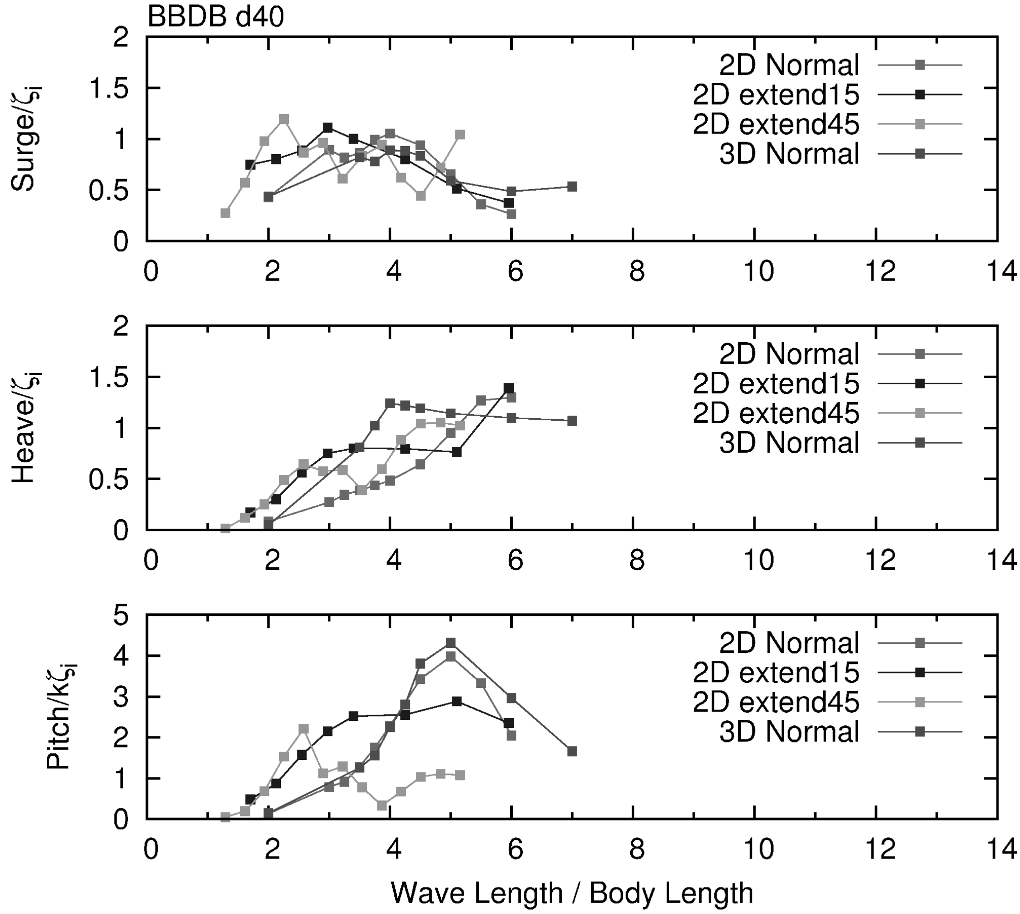

Fig.5 Motion amplitude

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