ABSTRACT

Waves are caused by winds blowing over the ocean surface. Ocean waves are an abundant, renewable, and non-polluting source of energy. Ocean wave energy is extracted from the surface motion of waves and transformed into electrical energy by using wave energy converters (WECs).

In the present study, the floating-type WEC is considered. An integrated procedure for hydrodynamic analysis and structural assessment of a floating-type WEC is addressed. To analyze the floating condition of the WEC, spring elements are used to prevent rigid-body motion without influencing the stress results. The load effects from inertial forces and the wave-induced force are considered in numerical computations. In addition, the effects of wave conditions, such as period, and incident wave angle, on the structural strength of the floating-type WEC are also considered.

The ANSYS finite element method is employed to numerically compute the behavior of the structure by using a quasi-static approach. In this study, effective use is made of basic research to design structural details, and the important insights obtained have been documented.

KEY WORDS: Floating; wave energy converter; structural analysis; finite element method.

INTRODUCTION

Fossil fuels refer to underground energy resources such as coal, oil, and natural gas that are utilized as fuel. Most of the energy consumed by people is obtained from fossil fuels. Although fossil fuels assist rapid industrial development, attempts to identify new energy resources to reduce dependence on fossil fuels and to promote the development of alternative energy sources have been made in recent years. This is because fossil fuels are a major contributor to the CO₂ emissions that cause global warming. Therefore, green energy—a non-polluting solution that resolves concerns about energy exhaustion—has emerged as an important research topic. According to the U.S. Energy Information Administration (EIA), the use of renewable energy is predicted to steadily increase alongside that of fossil fuels after 2020. For these reasons, numerous studies on green energy have been conducted.

Such studies report that the energy density of ocean waves is significantly high, and the U.S. Department of Energy has estimated their energy density to be 2 million MW for the entire world. A wave, which is a motion that propagates through the ocean, is accompanied by a transfer of energy. The energy from the surface motion of waves is extracted and transformed into electrical energy by using wave energy converters (WECs). WECs are divided into three types depending on the principle of operation: oscillating-water-column (OWC)-, wave-overturning-, and movable-body-type converters. A movable-body-type converter, which is addressed in the present study, operates such that the device absorbs energy from the transmitted translational and rotational motion of a moving device arising from a wave. This type of WEC has been rated as having high energy-conversion efficiency because it absorbs the wave energy directly. However, the structural vulnerability of movable-body-type WECs has become a growing concern because the devices are exposed directly.

WECs can also be categorized by the installation method into fixed- and floating-type converters. The fixed-type WEC located near the shore is generally considered more susceptible to wave loadings due to the characteristics of waves. However, this type of WEC has a disadvantage in that the construction cost increases depending on the ocean depth. Hence, interest in the floating-type WEC, which was proposed to address this issue, has grown in recent years. Furthermore, waves tend to increase in energy density as the ocean depth increases. Therefore, the deep seas could be developed as large-scale resources.

In the present study, a floating pendulum WEC—a type of floating movable WEC—is considered. The pendulum WEC was first proposed by a research group of the Muroran Institute of Technology, Japan (Watabe, 2005). They examined the characteristics of a fixed-type pendulum WEC at the sea of outside of Muroran harbor. The operating principles of the device are described in detail in the following section. The aim of this study is to assess the wave-induced structural response of the WEC by means of a proper procedure that integrates hydrodynamic and structural analyses. Hydro-structural analysis consists of three main sub-analyses: hydrodynamic load assessment, motion analysis, and structural analysis. The performance of the WEC device was evaluated under regular wave conditions by using frequency-domain floating body dynamics. The higher-order boundary element method (HOBEM) based on the potential flow model was used to obtain motion characteristics and wave forces acting on floating bodies. Details of this method are reported in Nam et al. (2011).