# Design Method on Plantship and Cold Water Pipe for Ocean Thermal Energy Conversion (OTEC)

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(海洋温度差発電のためのプラント船と深層水取水管の設計法)

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論　文　内　容　の　要　旨

Energy issue is one of the biggest issues in this 21st century. So many efforts have been done to ensure the sustainability of energy supply by changing the contribution of fossil fuels with renewable energy resources. For a country with a large area of tropical sea such as Indonesia, one of the prospective ocean energy resources to be developed is Ocean Thermal Energy Conversion (OTEC). Even though its potential is undeniable, it is relatively still unexplored due to high capital cost and unsettled design of the Cold Water Pipe (CWP) for being utilized in commercial scale.

Considering these issues as the research background, this thesis has two main subthemes. The first subtheme, as an effort to reduce the capital cost, introduces a concept design of the floating structure from converted oil tanker ship. The second subtheme is to design the Cold Water Pipe (CWP) based on the dynamic stability of the pipe. For convenience, the thesis is divided into 4 main chapters as follow:

Chapter 1, "General introduction", includes the general background, aims of the study, outline, and the overview of OTEC system in brief.
Chapter 2, "Preliminary design of a plantship", covers the historical overview of OTEC floating structure, method to design the floating structure from converted oil tanker ship, variables in the design process, result of the floating structure design and the general arrangement.
Chapter 3, "Design of Cold-Water Pipe (CWP) based on stability approach", presents the historical overview of OTEC CWP, method and case configurations to design the CWP, analytical and numerical simulation process, and result of the CWP design.
Chapter 4, "General conclusions and recommendations", states the general conclusions obtained from Chapters 2 and 3 along with the recommendations for future work.

Even though the whole chapters discuss all about the component of OTEC plantship, Chapter 2 more focuses on the design of the floating structure but Chapter 3 deals with the design of the CWP. Thus, to ease the readers for understanding the contents, Chapters 2 and 3 have each introduction, methods, conclusions and references in specific manners.

In Chapter 2, to propose the floating structure design process, the general principles of designing a converted tanker FPSO is adapted and then modified to deal with OTEC characteristic. In the design process, the arrangement of the OTEC layout is carried out by constraint satisfaction method and the prospective floating structure size is varied using Monte Carlo Simulation. The variables in the design process consist of the velocities of cold water and warm water transport, the size of the plantship, and the location of the OTEC equipment to the seawater tank. Constraints are introduced as allowable border to determine the acceptability for particular case including the provided space and buoyancy, and the net power output estimation. The results show that the `typical` size of Suez-max oil tanker ship is the optimum one for the plantship with the velocity of the water transport of 2-3 m/s. The general arrangement is also conceptualized in this chapter.

In Chapter 3, OTEC CWP is designed focusing on the effects of internal flow to the stability of the pipe. The design analysis is deliberated to select the pipe material, top joint configuration (fixed, flexible, pinned) and bottom supporting system (with and without clump weight). Initially, a fully coupled fluid-structure interaction analysis between the pipe and the ambient fluid is carried out using ANSYS interface referring an integration of Computational Fluid Dynamics (CFD) and Computational Structural Mechanics (CSM). Separately, the analytical solution is built by taking into account the components of the pipe dynamics and then solved via power series expansion by inserting the boundary conditions at the top joint connection and bottom supporting system. Using scale models, the results obtained from the analytical solution are compared with the ones from numerical analysis to examine the feasibility of the analytical solution. After being verified, the analytical solution is used to observe the dynamic behavior of the CWP for 100 MW-net OTEC power plant in full-scale model. The results yield conclusions that pinned connection at the top joint is preferable to decrease the applied stress, clump weight installation is necessary to reduce the motion displacement and Fiber Reinforced Plastic (FRP) is the most suitable material among the examined materials due to its light weight and high strength.

Gathering the process and results obtained from Chapters 2 and 3 together, Chapter 2 gives the required main scantlings of the CWP in which will be used as the input data to analyze the stability of the pipe in Chapter 3. Chapter 3 states the suitable material of the pipe and the necessity of clump weight installation so that the weight of the riser can be determined and can be used to calculate the total weight in Chapter 2. The general conclusion can be derived as follow: 1) It is possible to consider an oil tanker ship conversion as a plantship for OTEC power plant with pinned or flexible joint to attach the CWP on the plantship; 2) The seawater transport velocity plays an important role in both plantship size decision and pipe stability analysis.