Project:

Interaction of Floating Elastic Plates and Water Waves.

Research theme:
Mathematical and computational methods for the plate-water interaction.

Subjects:
Applied mathematics, hydrodynamics, fluid mechanics.

Participants:
Prof.dr.ir. Aad J. Hermans, projectleader; M.Sc. Olexiy I. Andrianov.

Affiliation:
Department of Applied Mathematical Analysis,
Faculty of Electrical Engineering, Mathematics and Computer Science,
Delft University of Technology.

Project description

Background

With a growing population and a corresponding expansion of urban development in land-scarce island countries and countries with long coastlines, the governments of these countries have resorted to land reclamation from the sea in order to ease the pressure on heavily-used existing land space. There are, however, constraints on land reclamation works, such as the negative environmental impact on the country's and neighbouring countries' coastlines and marine eco-system, as well as the huge economic costs in reclaiming land from deep coastal waters, especially when the sand for reclamation has to be bought at an exorbitant price. In response to both the aforementioned needs and problems, engineers have proposed the construction of very large floating structures (VLFS for short) for industrial space, airports, bridges, breakwaters, ferry pierces, storage facilities, military purposes, recreation parks and even habitation. Japan, Canada, Norway, USA, Vietnam have constructed such VLFSs already, China, Korea, Israel, Germany are planning to do so in nearest future. These structures have advantages over the traditional land reclamation solution in the following respects: they are cost effective when the water depth is large; environmentally friendly as they do not damage the marine eco-system, or silt-up deep harbours or disrupt the ocean currents; they are easy and fast to construct and therefore sea-space can be speedily exploited; they can be easily removed or expanded; and the structures on VLFSs are protected from seismic shocks since the energy is dissipated by the sea.

VLFSs may be classified under two broad categories, namely the pontoon-type and the semi-submersible type. The former type is a simple flat box structure and features high stability, low manufacturing cost and easy maintenance and repair. However, this pontoon-type of floating structure is only suitable for use in calm waters associated with naturally sheltered coastal formations. To further reduce the height of waves that impact on these pontoon-type VLFS, breakwaters are usually constructed nearby. In open seas where the wave heights are relatively large, it is necessary to use the semi-submersible type of VLFS to minimize the effects of waves while maintaining a constant buoyant force. The pontoon-type/mat-like VLFS is very flexible when compared to other kinds of offshore structures and so the elastic deformations are more important than their rigid body motions. Thus, hydroelastic analysis takes centre stage in the analysis of mat-like VLFSs.

There is another application of this study. The interaction between large ice fields and surface waves can be described by the same theory with inserting the ice physical properties in the problem instead of the plate properties.

Our research

The subject of our research is the hydroelastic behaviour of VLFS in waves and diffraction of surface waves by VLFS. So, the main idea in proposed concepts is to build a very large mat-like structure when the thickness of VLFS is very small in comparison to its horizontal parameters. In a practical situation the horizontal dimensions are about several kilometers by several hundred meters while the thickness and draft are in order of several meters. Therefore, a thin plate with elastic properties serves as a model for a VLFS.

The objective of the research is to derive an exact analytical solution and numerical results for the thin elastic plate of various shapes and dimensions. The considered geometrical sketches of the plate are of rectangular (strip, multiple strips) or arbitrary (circle, ring) shape. The wave length is smaller than the width of the floating plate and there is no space between the plate and the water. The solution for the plate deflection (vertical displacement), the waves' reflection and transmission is derived using different methods of applied mathematics, mechanics and fluid mechanics. New approaches for the hydroelastic analysis of VLFSs are proposed. We study the problem for different kinds of water depth: very shallow water when floating structures are located close to the coast, general and universal case of finite water depth, very deep water when structures are floating very far from the sea or ocean coast.

This research might be applied to predict the hydroelastic response of VLFS to water waves and the general behaviour of VLFS for different values of wave length, water depth and other physical parameters of the problem. To obtain numerical results we developed several program packages. The results of our work have been published in the scientific journals and presented at the international conferences. List of the publications is given below.

As a part of the project, it is planned that Mr. O.I.Andrianov will prepare Ph.D. thesis for the defence at Delft University of Technology in 2005. The subject of his thesis will coincide with the subject of the project described above.

Scientific publications:

1. ANDRIANOV A.I. & HERMANS A.J. (2002a). A VLFP on Infinite, Finite and Shallow Water. *Proceedings of 17th International Workshop on Water Waves and Floating Bodies*, Cambridge, UK, p.1-4.

2. ANDRIANOV A.I. & HERMANS A.J. (2002b). Diffraction of Surface Waves by VLFP on Infinite, Finite and Shallow Water *(abstract)*. *Abstracts of Day on Diffraction' 2002*, Saint Petersburg, p.12-13.

3. ANDRIANOV A.I. & HERMANS A.J. (2002c). Diffraction of Surface Waves by VLFP on Infinite, Finite and Shallow Water. *Proceedings of the International Seminar Day on Diffraction' 2002*, Saint Petersburg, p.13-23.

4. ANDRIANOV A.I. & HERMANS A.J. (2003a). The Influence of Water Depth on the Hydroelastic Response of a Very Large Floating Platform. *Marine Structures*, vol.16, iss.5, p.355-371.

5. ANDRIANOV A.I. & HERMANS A.J. (2003b). Hydroelasticity of Quarter-Infinite Plate on Water of Finite Depth. *Proceedings of 18th International Workshop on Water Waves and Floating Bodies*, Le Croisic, France, p.1-4.

6. ANDRIANOV A.I. & HERMANS A.J. (2003c). Hydroelasticity of a Circular Plate in Deep Water *(abstract)*. *Abstracts of Day on Diffraction' 2003*, Saint Petersburg, p.14.

7. ANDRIANOV A.I. & HERMANS A.J. (2004a). Hydroelasticity of a Circular Plate on Water of Finite or Infinite Depth. *Submitted to Journal of Fluids and Structures*, *to be published*.

8. ANDRIANOV A.I. & HERMANS A.J. (2004b). Hydroelasticity of Elastic Circular Plate. *Proceedings of 19th International Workshop on Water Waves and Floating Bodies*, Cortona, Italy, p.7-10.

9. ANDRIANOV A.I. & HERMANS A.J. (2004c). Hydroelastic Behaviour of a Ring-Shaped Plate *(abstract)*. *XXXII International Summer School - Conference Advanced Problems in Mechanics*, Repino, Russia.

10. ANDRIANOV A.I. & HERMANS A.J. (2004d). Interaction of Free Surface Waves and Floating Elastic Plates *(abstract)*. *Abstracts of Day on Diffraction' 2004*, Saint Petersburg.

Period of project:
Janury 2001 - September 2005.

Address:
TWA, EWI, TU Delft, Mekelweg 4, 2628 CD Delft, The Netherlands

Information:
Tel.: +31-15-2783613; fax: +31-15-2787295, email: a.i.andrianov@ewi.tudelft.nl.

Web:
http://ta.twi.tudelft.nl/users/andrianov, http://ta.twi.tudelft.nl/mf/users/hermans.