OCEAN ENGINEERING

Chia Chuen Kao
National Cheng Kung University, Taiwan

Keywords: Ocean engineering, field measurement and remote sensing, marine structures and materials, naval architecture, ocean energy, mariculture engineering, underwater acoustic, and harbor and navigation

Contents

Summary

Ocean Engineering refers to the application of engineering, planning, and management to the state-of-the-art in the field of oceanography. Oceanography is dictionary-defined as a science dealing with the oceans and includes the delimitation of their extent and depth, the physics and chemistry of their waters, marine biology, and the exploitation of their resources. That is, Ocean Engineering can be explained in terms of the practical implementation of science and mathematics by which the physics and chemistry properties of ocean water and the sources of energy in ocean are made useful to people. The quality of having utility and practical worth or applicability for human beings should be the most essential issues. If, however, there is potential for a significant adverse effect to any environmental quality, alternatives for avoiding or mitigate that possible adverse effect should be included to fulfill environmental equilibrium as well as economy benefits. Therefore, emphasis is placed on the solution of engineering problems related to the marine environment with thorough speculation of ecological and esthetic aspects of the environment.

Collections of articles serve to review a wide range of research topics and to illustrate the interrelationships among many types of problems encountered in Ocean Engineering. Seven selected areas are respectively *Field Measurements*, *Marine Structures and Materials*, *Naval Architecture*, *Ocean Energy*, *Mariculture Engineering (Sea Farming Systems)*, *Underwater Acoustics*, and *Harbor and Navigation*. One-paragraph highlights are surveyed in Section 1, Introduction. Section 2 through Section 8 of this investigation summarizes these chapters. These comprehensive review chapters written by discerning experts or professionals have distinguished lasting knowledge from the ephemeral and stimulated interested students, researchers and practitioners in thoughts.

1. Introduction

Ocean Engineering refers to the application of engineering, planning, and management to the state-of-the-art in the field of oceanography. Oceanography is dictionary-defined as "*a science dealing with the oceans and includes he delimitation of their extent and depth, the physics and chemistry of their waters, marine biology, and the exploitation of their resources*". That is, Ocean Engineering can be explained in terms of the practical implementation of science and mathematics by which the physical and chemical properties of ocean water and the sources of energy in ocean are made useful to people. The quality of having utility and practical worth or applicability for human beings should be the most essential issues. Therefore, a qualified ocean engineer requires not only a firm foundation in general education but also strong knowledge of ocean environment and its relationship to other sciences and engineering. Such background equips an ocean engineer with the tools to handle ocean engineering data processing, the engineering design of components and systems for usage in the ocean and application of these elements to the solution of engineering problems connected with work in or on the ocean in developing the resources of the oceans.

If, however, there is potential for a significant adverse effect on any environmental quality, alternatives for avoiding or mitigating the possible adverse effect should be included to maintain environmental equilibrium as well as economic benefits. As a result, a deliberate strategy should conduct a multidiscipline appraisal of the total impact of a given development project. The necessity for this appraisal at the planning and design stage is apparent and regulated by law in most countries. Nowadays emphasis is placed on the solution of engineering problems related to the marine environment with thorough consideration of ecological and esthetic aspects of the environment. A further requirement is recognized for additional baseline data and knowledge of the quantitative ecological physical relationships. This information can be developed by monitoring before, during, and after construction effects on any ocean engineering projects.

In recent years rapid flow of new literature has flooded our world but not every new idea gets equal share of perspective and originality. What will be the next phase of a given branch when neo-concept seems poised for a surge of growth? Scientists and engineers of all branches attempt to keep up with mushrooming knowledge without becoming too narrowly specialized and to discriminate a burgeoning technology trend from the newfangled gadget. Collections of reviews covering broad sectors of science and engineering are still the best way of sifting incoming commentaries critically. Hereof, seven selected areas illustrate the interrelationships among many types of problems encountered in ocean engineering. They are *Field Measurements*, *Marine Structures and Materials*, *Naval Architecture*, *Ocean Energy*, *Mariculture Engineering (Sea Farming Systems)*, *Underwater Acoustics*, and *Harbor and Navigation*. Each chapter will review and illuminate the development of scientific understanding of a specific topic. Section 2 through Section 8 of this investigation summarizes these chapters. Highlights are from the techniques of ocean surveillance actively carried out to investigate the body of water above, on, and below the surface to the technology of getting ships from place to place with latest method of determine position, course and distance traveled. These comprehensive review articles written by discerning experts or professionals have distinguished lasting knowledge from the ephemeral and stimulated interested students, researchers and practitioners in thoughts. Following seven paragraphs will demonstrate overviews on each subject briefly.

"*Field Measurements*" discusses two of the fundamental issues concerning measurements of ocean environmental data, namely, *in situ* and by remote sensing. A field measurement is termed *in situ* if the sensor or instrument has a direct contact with or in a very close proximity of the medium being measured. On the other hand, remote-sensing methods resort to the measurement from a distance and usually conducted using electromagnetic waves. Generally speaking, *in situ* measurements can provide continuous and long-term data at a single location whereas remote-sensing measurements can supply data for a wide region. The highlights of the chapters are wave, ocean current, and wind measurements and their applications in the ocean engineering areas. The problems associated with natural or manmade damage, data accuracy, and gauge and fixture durability will also be reviewed.

"*Marine Structures and Materials*" introduces various engineering facilities constructed for the exploitation of marine resources and the continuity of economic development in the sea or along the shoreline. The classification of marine structures may depend on mobility, function, or located terrain, comprised definition and catalog of marine structures, design criteria and methods of marine structures, selection of material for marine structures and the research perspectives of future marine structures. At present, modern ocean technology is calling for a sophisticated and practical approach to the structure design for deep ocean exploitation, from concept to completion.

A comprehensive review on design consideration for “*Navel Architecture*”, is the manner in which the components of vessels are organized and integrated based on owners’ requirements. A formation of ship hull or construction, as or as if is the result of conscious art. The practice of designing and fabricating watercrafts can be classified by their means of physical supporting forces or their intended purposes. Three kinds of water lift methods are aerostatic, hydrodynamic, and hydrostatic. Merchant ships, naval vessels, working craft and pleasure craft are classified according to the intended purposes. The main characteristics of seven types of propellers are also described.

When viewing the world’s future energy supply, there is the demand to exploit alternative energy in order to sustain and further develop the activities of humankind. Greater attention has come to be focused and high expectations come to be placed on “Ocean Energy” because the ocean provides a vast energy resource capable, theoretically, of meeting all our needs if only we can find effective ways to extract. The oceans are the world’s largest solar energy collector and storage system. A lot of usable power can be generated from the ocean. No only currents, waves, and tides with dynamic exertion but also ocean thermal energy conversion applies to power expended or capable of being transformed into work. These means of supply of energy are feasible with proper devices; however, more researches are necessary to provide greater confidence in technical and economic feasibility.

The general picture of “*Underwater Acoustics*” covers the history in regard to research and investigation of underwater acoustics. Then, the sound velocity profile, which is an important factor for acoustic wave propagation at sea, is also described. In addition, the approaches for measurement of the speed of sound in water are also discussed and are categorized into two kinds of methods. Furthermore, acoustic phenomena in ocean are covered. The phenomena of wave propagation in ocean acoustics, such as: surface duct, shadow zone and SOFAR channel, are discussed in terms of their occurrence and application. Propagation wave models for various ocean environments are discussed. Three sophisticated propagation models that are acoustic ray model, normal mode model and PE (parabolic wave equation) model will be discussed. The application of echo sounder for detection of fish and depth of ocean bottom as well as the bioacoustics of marine life and other applications of underwater acoustics in the ocean are included.

“*Mariculture Engineering (Sea Farming Systems)*” or sea farming technology can be stated as the cultivation of marine organisms in their natural environment. Today, hefty research efforts to produce some fish species under artificial conditions have given significant results when it comes to volumes. The technological progress towards a sustainable industry has mainly been focused on two areas: artificial reef and cage technology, as well as feeding technology. Reasons for the success of the sea farming industry are the well-suited coastline for growing of general water-fish species and the well-developed coastal infrastructure. In addition to the general research on biological matters, the research has resulted in large steps forward when it comes to vaccine development, feed development as well as development in farm technology and farming strategies.

Harbors afford a place of safety for vessels in a protected water area where vessels may deliver or receive cargo. The harbor activities include approaches and anchorage and commercial part where the quays, wharves, facilities for transfer of cargo, docks, and repair ships are studied. Then, getting ships from place to place soundly involves the method of determining position, course, and distance traveled. "*Harbor and Navigation*" also embraces all knowledge pertaining to performing engineering tasks of all related structural features in the ocean environment where waves propagate differently from waves in open sea and influence harbor-associated construction.

2. Field measurement and remote sensing

2.1. Overview

Oceans are only furious and unpredictable; many sorts of natural hazards threaten humans and properties such as beach erosion, coastal flooding, and water level changes due to global green house effect. Therefore, field environmental data are essential for ocean engineering designs, constructions, operations, studies, and other related activities. Many types of oceanographic data can be measured, such as waves, ocean current, wind, temperature, atmospheric pressure, water vapor, water depth, precipitation, radiation, conductivity, turbidity, dissolved oxygen, chlorophyll, and so forth. These data can be categorized into two types according to corresponding measuring methods, in-situ and remote sensing. A field measurement is termed *in situ* if the sensor or instrument has a direct contact with the medium. If a sensor, which is in a very close proximity of the medium, uses a remote method (e.g., acoustic or electromagnetic) to measure, it can be called a remote *in situ* measurement. Sensors of *in situ* measurements need to be installed on structures. Remote sensing measurement is the measurement that is made from a distance and has no direct contact with the medium. Remote-sensing instruments can be placed on aircraft, satellites, or on the land. Generally speaking, *in situ* measurements can provide continuous and long-term data at a single location whereas remote-sensing measurements can provide data over wide range and region. However, airborne or space-borne remote sensing measurements are only available when aircraft or satellites move over/above the designated area. Land-based remote sensing can perform likewise, but measurements are confined to coastal areas.

2.2. *In situ* Measurements

In situ wave measurements can be conducted on either fixed or floating structures. For point (or unidirectional) waves, sensors installed on a fixed structure or sea floor include wave staff (step-contact, resistance, capacitance, and Baylor types), subsurface pressure sensors, particle velocity sensors, acoustic wave sensors, laser wave sensors, and radar wave sensors. However, these sensors are usually limited to coastal or shallow water areas because (1) structures are rarely available in deep water and (2) accuracy of some sensors decreases rapidly with respect to depth. In deep water, data buoys may be an alternative to measure wave information. The accelerometer on a buoy measures the motion of the buoy, and the buoy motion is converted to water surface motion (i.e., waves). Installing either three mutually orthogonal sensors at the same location (e.g., pressure sensor and two horizontal velocity components) or a spatial array can do measuring directional waves at a fixed structure or from sea floor. Directional waves can also be measured from buoys based on one of the following three principles: (1) surface slope following, (2) particle following, and (3) orbital following principles.

There are two types of *in situ* current measurements: Eulerian and Lagrangian. A Eulerian current meter, which measures ocean currents at a fixed location, can be installed on a structure, placed on sea floor, or attached to a buoy/mooring. The Eulerian current meters include mechanical current meters (either propeller or cup types), acoustic current meters (standard or Doppler), and electromagnetic current meters. Drifters, either surface or subsurface drifters, are used for Lagrangian current measurements (which measure ocean currents by following individual parcels of water). Satellites, ship or land-based radar, radio wave navigation system, and Global Positioning System (GPS) to determine current speed and direction can track locations and trajectories of drifters.

Wind sensors for *in situ* measurements can be categorized into (1) hot film anemometers, (2) mechanical anemometers (cup, vane, and propeller types), (3) acoustic anemometers, and (4) a radar wind profiler. If an anemometer is installed on a fixed structure, the location of the sensor needs to be carefully chosen to avoid blockage effects. If the sensor is installed on a floating platform, it needs to consider if the motion of the platform affects the measurement. Due to the effect of the marine boundary layer, the elevation of the measurement will affect the wind speed measurement. Thus, wind speeds measured at different elevations need to be converted to a common or standard elevation (say 10 meters above MWL) for further application, analysis, or comparison.

In-situ sensors, instruments, and their supporting structures deployed in oceans will experience various environmental problems in addition to the forces from wind, wave, and current. These problems include marine fouling and growth, marine corrosion, salt-water intrusion, salt buildups, damages from sea animals, etc. All these problems will (1) damage the sensors and the structures, (2) affect the accuracy of the measurements, and (3) reduce the service time and survivability of the sensors and their supporting structures.

2.3. Remote Sensing Measurements

Wave, wind, and ocean current data can also be measured using remote sensing techniques. Airborne and satellite-borne remote sensing sensors include radar altimeters, scatterometers, synthetic aperture radar (SAR), surface contouring radar, and aerial and stereo photographs. Land-based sensors include short-range ship radar, Doppler radar, and high frequency radar. Wave, wind, and current data from remote sensing measurements are derived from the remotely sensed raw data. The types of raw data and data processing algorithms/procedures vary from sensor to sensor. Due to the complexity of remote sensing, validation experiments and empirical correction relationships (using *in situ* measurements as references or ground truths) are needed to ensure the accuracy of remote sensing measurement.

Although remote sensing measurements are becoming very popular and are widely used in oceanography, meteorology, and studies of air-sea interaction, *in situ* measurements are still the primary methods used to obtain environmental data for ocean engineering applications. Some of the reasons are:

(1) most remote sensing measurements can only provide data when their supporting platforms pass over the measurement locations so they cannot measure continuous, long-term, and regular data as required for most ocean engineering applications;
(2) although remote sensing measurements can provide data covering much larger and wider areas, most of ocean engineering applications are very localized and need data for much smaller areas;
(3) some data information that is critical for engineering applications is not available from some remote sensing measurements (e.g., wave spectrum information is not available from altimeter systems);
(4) time and spatial resolution of some remote sensing measurements are too coarse; and (5) it is relatively easier to plan and set up an *in situ* measurement, and is cheaper, especially for long-term and regular measurements.

Note that the remote sensing techniques and space technology are being extensively studied and developed. Ocean environmental data from remote sensing measurements will become popular and useful to the ocean engineering applications when (1) the availability of satellites and aircraft increases, (2) the remote sensing techniques become more mature, and (3) the cost of remote sensing measurement is greatly reduced.

2.4. Data Quality Control of Field Measurement

A field measurement cannot be considered successful unless it can be proved that the measured data are accurate and reliable. Data quality control (QC) is conducted to make sure the whole measurement system works correctly and the final data truly represent the real environmental conditions. Generally speaking, data QC is based on three common principles:

(1) Reasonability: Data should be in reasonable ranges and intervals. The “range check” is commonly used to check if values of the measured data fall into a reasonable range. Specifying the maximum and minimum expected values sets up this range. For marine environmental data, the maximum and minimum values also depend on locations, seasons, and sensors used in addition to the theoretical and physical limits.
(2) Continuity: Data should maintain continuity in both time and space if no special atmospherically events or oceanographic features exist. Since environmental data measured at a specific location usually do not change drastically in time, a time-continuity check which checks the time rate of change of measured data can be set up and used for data QC. Data measured from nearby measurement stations can be used to check the data correctness and quality.
(3) Consistency (or correlation): Data should have proper time correlation, spatial correlation, and correlation with other measurements. For example, based on the characteristics of the wave-generation process, the relationship between wind and

high-frequency waves can be used as a consistency check for wave data. Data obtained from numerical or prediction models can also be used to check if measured data or the trends of the data are reasonable.

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Biographical Sketch

Prof. Dr.-Ing. Chia Chuen Kao is a Chinese born in Taiwan. He earned the B.Sc and M.S degree from National Cheng Kung University in Taiwan and his Dr.-Ing. degree from Hannover University in Germany. His doctorial thesis deals with the wave forces on the underwater pipelines with emphasis on the effect of the bottom boundary. Since 1983 he works at National Cheng Kung University, started as associate professor and then promoted to professor in 1989. Prof. Kao is a well-trained coastal and offshore engineer. He offers 'wave theory', 'civil engineering in the ocean' and 'flow induced vibrations' courses in the post-graduate program. In 1998, Dr. Kao founded Coastal Ocean Monitoring Center at National Cheng Kung University, which is currently the unique institution responsible for the operational oceanographic observation network around Taiwan. In recent years, Dr. Kao pays his attention on the offshore wind energy development.

In 1997, Dr. Kao initiated together with Prof. Soeren Kohlhase of Rostock University in Germany the 'Chinese-German Bilateral Seminar on Recent Development in Coastal Engineering', which was held every other year alternatively in both countries. In 2002, they invited Prof. Yi-Xin Yan of Hohai University in China to co-organize the 'Chinese-German Trilateral symposium on Coastal and Ocean Engineering'. The Symposium offers a platform for the scientists and engineers to discuss the research results in the relative fields. Through the personal contacts in the symposiums, the academic activities toward the mutual benefit, such as the joint research project and the student exchange, etc., have been enhanced.